# GEOPHYSICAL SURVEYS
# WITH FDEM METHODS
# EWA MARINA,
# CAMPBELL INDUSTRIAL PARK
# AND BARBERS POINT HARBOR
# OAHU, HAWAII

# GEOPHYSICAL SURVEYS
# WITH FDEM METHODS
# EWA MARINA, CAMPBELL INDUSTRIAL PARK
# AND BARBERS POINT HARBOR
# OAHU, HAWAII

**Prepared For:**

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**August 8, 1990**

**(Our Job #90029)**

## Table of Contents

## 1.0 EXECUTIVE SUMMARY

A geophysical survey was conducted in three areas in the vicinity of the Barbers Point Naval Air Station on Oahu, Hawaii. The areas are designated as Ewa Marina, Campbell Industrial Park, and Barbers Point Harbor.

The objective of the survey was to infer from the geophysical data information about the thickness of a brackish water lens floating on saline water in the limestone aquifer of this region. A geophysical method was employed that allows relatively quick areal coverage for determining lateral variation in the thickness of the brackish water lens. To also derive from the survey information about the thickness of the brackish water lens, the geophysical data was correlated to salinity observations in boreholes placed in the three survey areas.

The results of the survey are given as profiles of the thickness of the brackish water lens along lines generally perpendicular to the shore. The profiles are mainly characterized by a rapid increase in the thickness of the brackish water lens in the first 150 ft from the shore. The thickness of the brackish water lens varies from about 100 ft in the Ewa Marina area to less than 50 ft in the Barbers Point Harbor area.

## 2.0 INTRODUCTION

This report contains the results of geophysical surveys conducted on the island of Oahu, Hawaii for Haseko (Hawaii) Inc. (Haseko) by Blackhawk Geosciences, Inc. (BGI).

The objective of the work was to infer from electrical resistivity measurements information about salinity distribution in ground water. In this coastal plain area the bedrock is a limestone/dolomite and a lens of brackish water rests on highly saline water. The thickness of this lens changes rapidly with distance from the shore. The mapping of the lateral and vertical variation in the thickness of this brackish water lens was the dominant objective of this survey at specific areas on the coastal plain near the Barbers Point Naval Air Station. Surveys were conducted at three sites; Ewa Marina, Barbers Point Harbor, and Campbell Industrial Park. In some of the areas construction of marinas alters the distribution of salinity. The geophysical surveys were utilized to both determine base line data prior to construction, as well as changes caused by construction.

The geophysical method utilized was frequency domain electromagnetic (FDEM) measurements with the Geonics EM-34. The EM-34 is a rapid and inexpensive method sensitive to lateral changes in resistivity. Data coverage in the three areas was limited by cultural noise and access constraints.

Although the particular geophysical method employed finds its main utility in mapping lateral changes, it can also be utilized for determining vertical salinity distribution when borehole information is available for calibration. A number of salinity profiles measured in boreholes placed near the three survey areas was made available and was used to derive vertical salinity variations also.

# 3.0 DATA ACQUISITION

## 3.1 GENERAL

The field work was performed by two BGI geophysicists from June 1 to June 6, 1990. Data was acquired at three sites near the southwest shore of the island of Oahu. The sites and locations at boreholes and survey lines are shown on Figure 3-1 for Ewa Marina, Barbers Point Harbor, and Campbell Industrial Park. Prior to this survey, test data were acquired on May 22, 1990 along lines 1400W and 0 to evaluate the usefulness of the method. A report covering the results of the test survey were delivered to Haseko in May 1990. The data from the previous test survey have been incorporated into this report. The area surveyed and specific acquisition problems for the sites were as follows:

(1) At Ewa Marina, surveys were conducted along pre-existing roads and brushed lines perpendicular to the shoreline with one additional line traversed parallel to the shore. Eight of the thirteen survey lines required a brush cutting crew due to the thick vegetation.

(2) At Barbers Point Harbor five lines were surveyed perpendicular to the new harbor. No lines were possible at the original shoreline due to the presence of facilities, such as gas pipelines and utility lines.

(3) At Campbell Industrial Park three lines were surveyed perpendicular to the shore.

The instrument employed was the Geonics EM-34. The manufacturer's specifications and principles of operation for the EM-34 are given in Appendix A. A daily log of field activities is given in Table 3-1.

The EM-34 measurement stations along lines perpendicular to the shore were usually separated by 25 ft intervals for the first 300 ft and by 50 ft intervals thereafter. The readings of conductivity (in mmhos/m) were taken with 10 m, 20 m and 40 m transmitter-receiver separations with both coils vertical and coplanar. The effective depth of exploration of the EM-34 at 10 m, 20 m and 40 m separation is approximately 25 ft, 50 ft and 100 ft, respectively. Prior to interpretation field conductivity readings were corrected for non-linearity at high values of conductivity (Appendix A).

*Table 3-1. Daily Log of Field Activity*

| Date (1990) | Activity |
|---|---|
| May 31 | BGI personnel mobilize from other Hawaii geophysical surveys to Honolulu, HI. |
| June 1 | Meet with Tom Nance to discuss EM-34 survey areas. Establish survey grid for Ewa Marina area. (Use benchmark located on shoreline and road junction (Line 0) as 0,0 for survey grid). Start brush crew on survey lines. Data taken on Line 0N, STA 0 to 1400W and STA 0 to 2000E (10, 20 and 40 m coil separations). |
| June 2 | Ewa Marina Area.<br>Data taken on Line 0N, STA 2000E to 3600E.<br>Data taken on Line 3600E, STA 0N to 400N.<br>Data taken on Line 3200E, STA 0N to 650N. |
| June 3 | Move to Barbers Point Harbor Area. Allow for brush crew to get ahead.<br>Data taken on Line 1, STA 0N to 600N.<br>Data taken on Line 2, STA 0N to 600N.<br>Data taken on Line 3, STA 0N to 1000N.<br>Data taken on Line 4, STA 0N to 600N.<br>Data taken on Line 5, STA 0N to 600N. |
| June 4 | Ewa Marina Area.<br>Data taken on Line 400W, STA 0N to 600N.<br>Data taken on Line 800W, STA 0N to 600N.<br>Data taken on Line 1200W, STA 0N to 600N.<br>Data taken on Line 1400W, STA 0N to 600N. |
| June 5 | Move to Campbell Industrial Park Area. Allow for brush crew to get ahead.<br>Data taken on Line 1, STA 0N to 600N.<br>Data taken on Line 2, STA 0N to 600N.<br>Data taken on Line 3, STA 0N to 600N.<br><br>Ewa Marine Area.<br>Data taken on Line 550E, STA 0N to 600N.<br>Data taken on Line 1050E, STA 0N to 600N. |

*Table 3-1. (Continued)*

| Date (1990) | Activity |
|---|---|
| June 6 | Ewa Marina Area.<br>Data taken on Line 1500E, STA 0N to 300E (line not brushed).<br>Data taken on Line 2100E, STA 0N to 600E.<br>Data taken on Line 2400E, STA 0N to 500E. |
| June 7 | Demobilize BGI personnel and equipment to Golden, CO. |

EWA QUADRANGLE
HAWAII – HONOLULU CO.
ISLAND OF OAHU

BP boreholes 40, 80, & 150 feet from shoreline

BARBERS POINT HARBOR

WATER PIPE

CONCRETE REINFORCED SLAB

LINE 1

LINE 2

LINE 3

LINE 4

LINE 5

LINE 6

PIPELINE

JCIP boreholes near line 3 at 100, 200, & 300 feet from shoreline

PIPELINE AND POWERLINE INLET

CAMPBELL INDUSTRIAL PARK

EWA MARINA boreholes 1,2,3,4,&5 along line 0 at 30, 60, 100, 300,& 600 feet from shoreline

LOW LAND MARSH

LINE 0

1400W 1200W 800W 400W LINE 0 550E 1050E 1500E 2100E 2400E 3200E 3600E

EWA MARINA

Honokai Hale

Puu Kapolei

KAPOLEI PARK

Tenney Village

Varona Village

Gilbert

Barbers Point

Coral Pit

Abandoned Airfield

Tower

Beacon

Pumping Sta

Borrow Pit

Barbers Point Beach Park

Barbers Point Light

COAST GUARD RESERVATION

NAVAL AIR STATION

BARBERS POINT

GOLF COURSE

OIL REFINERY

CAMP MALAKOLE MIL RES

Flume

Gulch

Water Tank

Disposal

Landing Strip

ROAD

BLVD

ABANDONED

AQUEDUCT

MALAKOLE

KALAELOA

WAIMANALO

GEIGER

HANSON

ROOSEVELT

INDEPENDENCE

SARATOGA

HORNET

FRANKLIN

MIDWAY

ATTU

KAUHI

KUHELA

OLAI

HANUA

ELROD

SOUTH

CORAL SEA

TRIPOLI

NIMITZ

BEACH

OAHU

HAWAIIAN ISLANDS

LOCATION MAP

2000 0 2000

SCALE - FEET

BLACKHAWK GEOSCIENCES, INC.

EM34 LINE LOCATION MAP

HASEKO (HAWAII), INC.

EWA Marina, Campbell Ind. Park and Barbers Point Harbor

PROJECT NO.: 90029

Figure 3-1

# 4.0 INTERPRETATION RESULTS

## 4.1 GENERAL

The EM-34 geophysical instrument is mainly used to obtain lateral changes in ground conductivity. The effective exploration depth of the EM-34 measurements was varied from about 25 ft to 100 ft, so that lateral changes in salinity within a depth of about 100 ft in principle are reflected in the measurements. The EM-34 surveys are generally not used to determine vertical changes in resistivity because too few data points at different effective exploration depths are obtained to perform meaningful inversions.

In this survey, however, vertical changes in salinity can be inferred from the geophysical data by carefully correlating the geophysical readings with salinity profiles measured in boreholes near the survey lines. The borehole salinity profiles were made available by Tom Nance.

## 4.2 CORRELATING GEOPHYSICAL DATA TO SALINITY PROFILES MEASURED IN BOREHOLES

The thickness of the brackish water lens (depth to brackish water-saline water interface) was measured in a series of wells perpendicular to the shore near each site (for line and well locations see Fig. 3-1). The well information was provided by Tom Nance and is summarized in Figures 4-1, 4-2 and 4-3. Because accurate vertical survey control (elevation) was not established along the geophysical survey lines, in all further discussions depths will be referenced from the surface of the ground.

The borehole information from Ewa Marina (Fig. 4-1) typically shows a zone of constant salinities (less than 7 parts per thousand) for the upper 20 ft, followed by a zone of rapid increase in salinities (transition zone) followed by a leveling off of salinities in the bottom of the holes at values between 25 and 28 parts per thousand. The boreholes at the Campbell Industrial Park follow this same general pattern (Fig. 4-2). However, boreholes at Barbers Point Harbor area exhibit a different pattern of salinity versus depth (Fig. 4-3). In boreholes BP40 and BP150 the transition zone occurs at shallow depth (less than 10 ft) and borehole BP80 displays salinity values greater than 24 parts per thousand from near surface to the bottom of the hole.

For purposes of further analysis, saline water is defined by salinity values in excess of 24 parts per thousand, or at the end of the transition zone in the salinity profile. Using this definition, depth to saline water for each borehole is tabulated in Table 4-1. Table 4-1 shows that the largest variation in depth to saline water is observed in the boreholes at Ewa Marina.

For that reason the borehole data at Ewa Marina is best suited for calibration of the geophysical data.

**Table 4-1. Depth to saline water from borehole salinity logs**

| Borehole | Approximate Depth to Saline Water (ft below surface) |
|---|---|
| | (Ewa Marina Data from 07/02/90) |
| #1 | 47 ft |
| #2 | 50 ft |
| #3 | 63 ft |
| #4 | 70 ft |
| #5 | 86 ft |
| | (Campbell Industrial Park data from 07/27/90) |
| JCIP-100 | 40 ft |
| JCIP-200 | 40 ft |
| JCIP-300 | 40 ft |
| | (Barbers Point Data from 07/27/90) |
| BP-40 | ≈ 15 ft |
| BP-80 | 0 ft |
| BP-150 | ≈ 15 ft |

A cross-plot of EM-34 readings at 40 m coil separation adjacent to boreholes versus the thickness of the brackish water lens measured in those holes for the Ewa Marina area is shown in Figure 4-4. To verify the consistency of the observed relationship with theoretical concepts, calculations were performed using the theory set forth in Appendix A for the data from Ewa Marina. The following assumptions were made in these computations:

(1) The physical setting of a brackish water lens floating on saline water was approximated by a two-layer conductivity model. The conductivity of the first layer corresponds to brackish water saturated rock, and the conductivity of the second layer to saline water saturated rock. The model thus contains three variables, i.e.,

- conductivity of first layer, $\sigma_1$ (brackish water)
- conductivity of second layer, $\sigma_2$ (saline water)
- thickness of first layer, $h_1$ (depth from surface to saline water).

The objective is to determine the thickness of the first layer, therefore values for $\sigma_1$ and $\sigma_2$ must be obtained or assumed to compute $h_1$.

(2) The value of $\sigma_1$ was set equal to the conductivity reading with the EM-34 at 20 m coil separation. The justification for this is that the effective exploration depth at 20 m is about 50 ft, and the depth to saline water in boreholes #2, #3, #4 and #5 at Ewa Marina is greater than 50 ft. The EM-34 reading at 20 m coil separation, is, therefore, mainly influenced by the limestone saturated with brackish water. The EM-34 readings at 10 m coil separation were not used for this purpose, because near surface variation in conductivity (e.g., near surface salt water in marshes) have a major influence on these readings.

(3) The conductivity, $\sigma_2$, of the saline water was derived by matching the value of $h_1$ observed in boreholes with computed values for the EM-34 at 40 m coil separation. The value for $\sigma_2$ that best matches the data was 778 mmhos/m.

Using the approach described above, the data in Figure 4-4 shows that a reasonable agreement exists between the thickness of the brackish water lens measured in boreholes and thicknesses computed from theoretical considerations. The relation displayed by the solid line was subsequently used to derive profiles for the thickness of the brackish water lens along the survey lines at Ewa Marina.

The relation shown on Figure 4-4 was derived using salinity profiles measured in boreholes in the Ewa Marina area. Similar relations could not be established for the two other areas, mainly because the thickness of the brackish water lens did not vary much between the boreholes. At Campbell Industrial Park and Barbers Point Harbor a value for $\sigma_1$ was obtained from the average of the 10 m data, the value for $\sigma_2$ was left at 778 mmhos/m, and the depth was directly calculated using formulae outlined in Appendix A.

## 4.3 EWA MARINA

Profiles of the calculated thicknesses of the brackish water lens are shown in Figure 4-5. Changes in elevation along the lines have not been compensated for. The results for the conductivity profile taken parallel to the shore (line 0N) was highly influenced by its proximity to the ocean, and so no depth calculations were performed for this line. The field data for this line and all other field data are listed in Attachment 1. Also, the readings recorded on line 1400W were influenced by its

proximity to a metal fence, and the results along this line are omitted from Figure 4-5.

From the profiles shown in Figure 4-5 several features are apparent:

(1) On all lines the brackish water lens thickens rapidly with distance from the shore. At distances greater than about 300 ft from the shoreline the lens thickness is relatively constant.

(2) A comparison of the thickness of the lens observed in boreholes with calculated thicknesses from geophysical data on line 0 shows good agreement.

(3) Line 400W shows the thickest brackish water lens at about 110 ft. Lines east and west of 400W show lens thicknesses typically on the order of 80 ft to 100 ft.

On all lines at Ewa Marina high conductivity values were observed in the EM-34 data at 10 m coil separation near the shoreline because of its shallow effective exploration depth. On two lines (1200W and 800W) near surface high conductivities were also recognized on the north sides of the line. The high conductivities are likely caused by near surface high salinities in low lying marsh areas.

### 4.4 CAMPBELL INDUSTRIAL PARK

The locations of the three lines surveyed at the Campbell Industrial Park area are shown in Figure 3-1. The calculated profiles of depth to saline water for these lines are given in Figure 4-6, and the field data are given in the attachment. The borehole information has been superimposed upon the depth profile for line 3 in Figure 4-6.

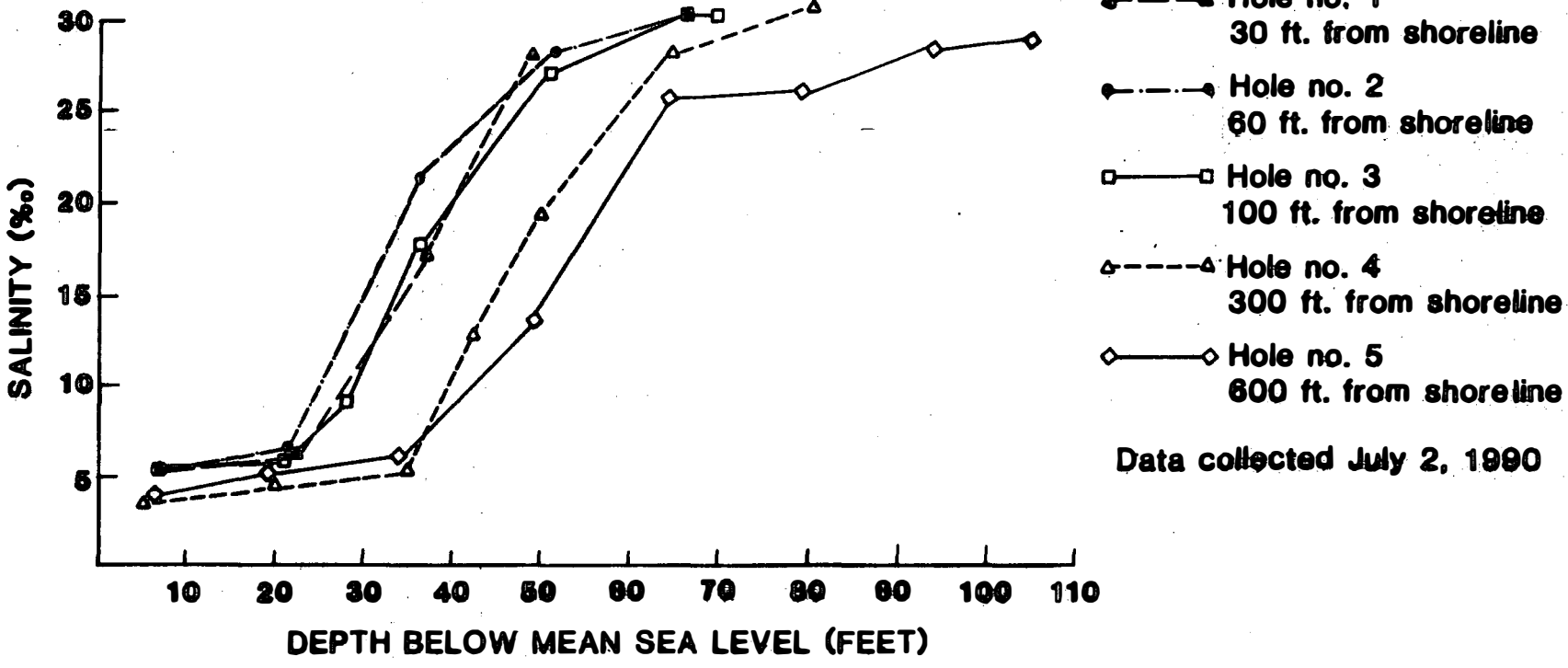
The discrepancy between borehole results and calculated depths along line 3 occurs near the shoreline and is believed to be mainly due to two factors:

(1) The recordings with the EM-34 at 40 m coil separation averages ground conditions over an area of about 40 m (120 ft) compared to a few inches in a borehole. This is an important consideration in areas with steep gradients in the thickness of the brackish water lens.

(2) The computations do not adequately take into account the near surface pockets of high salinity.

## 4.5 BARBERS POINT HARBOR

The calculated depth to saline layer along the five survey lines at Barbers Point Harbor are shown in Figure 4-7. The boreholes were not placed along these lines and have, therefore, not been superimposed on the computed profiles in Figure 4-7. The profiles are characterized by relatively small thicknesses of the brackish water lens, generally less than 50 ft. That information is consistent with the off-line boreholes that also show saline water to occur at shallow depth.




BLACKHAWK GEOSCIENCES, INC.

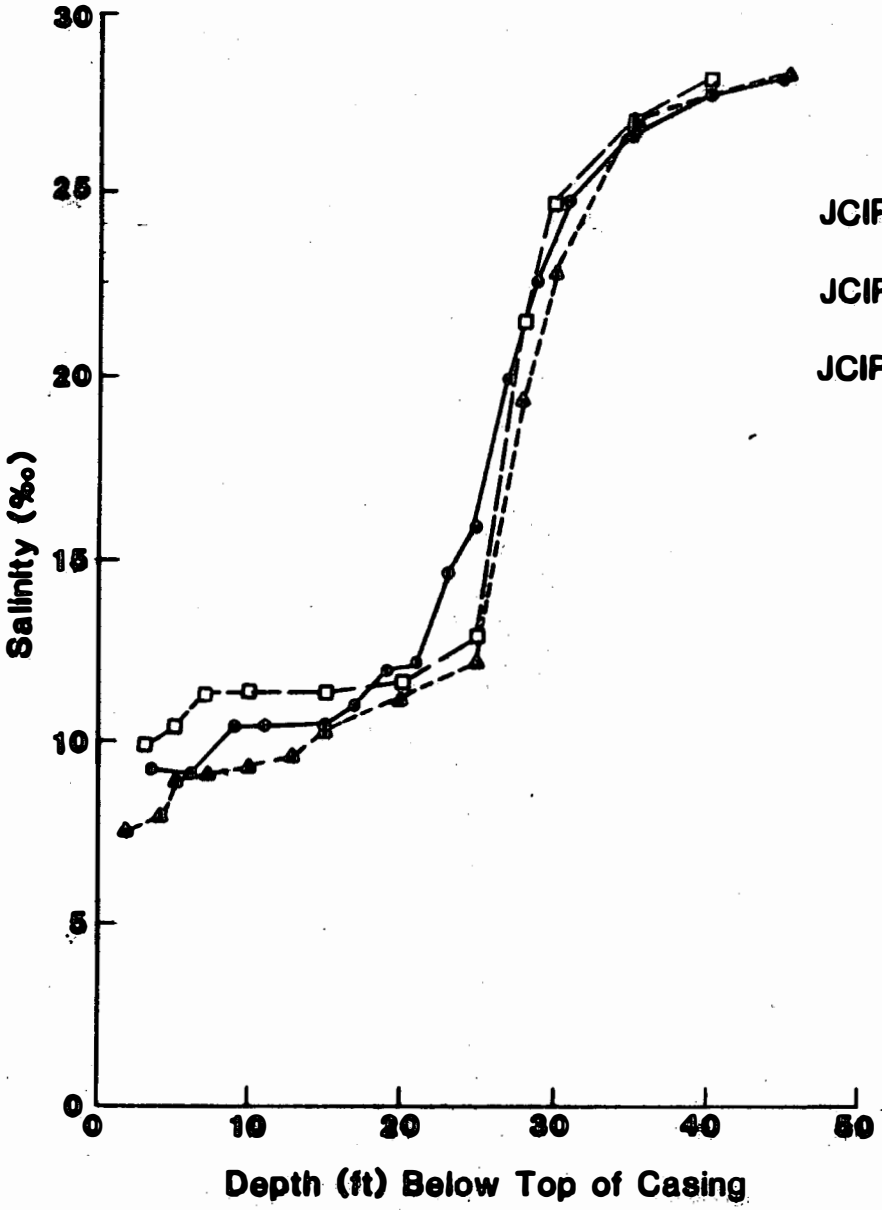
SALINITY PROFILES

EWA MARINA

*HASEKO (HAWAII), INC.*

PROJECT NO: 90029

Figure 4-1




JCIP-100 ●——● 100 Feet from shore

JCIP-200 □— — —□ 200 Feet from shore

JCIP-300 ▲------▲ 300 Feet from shore

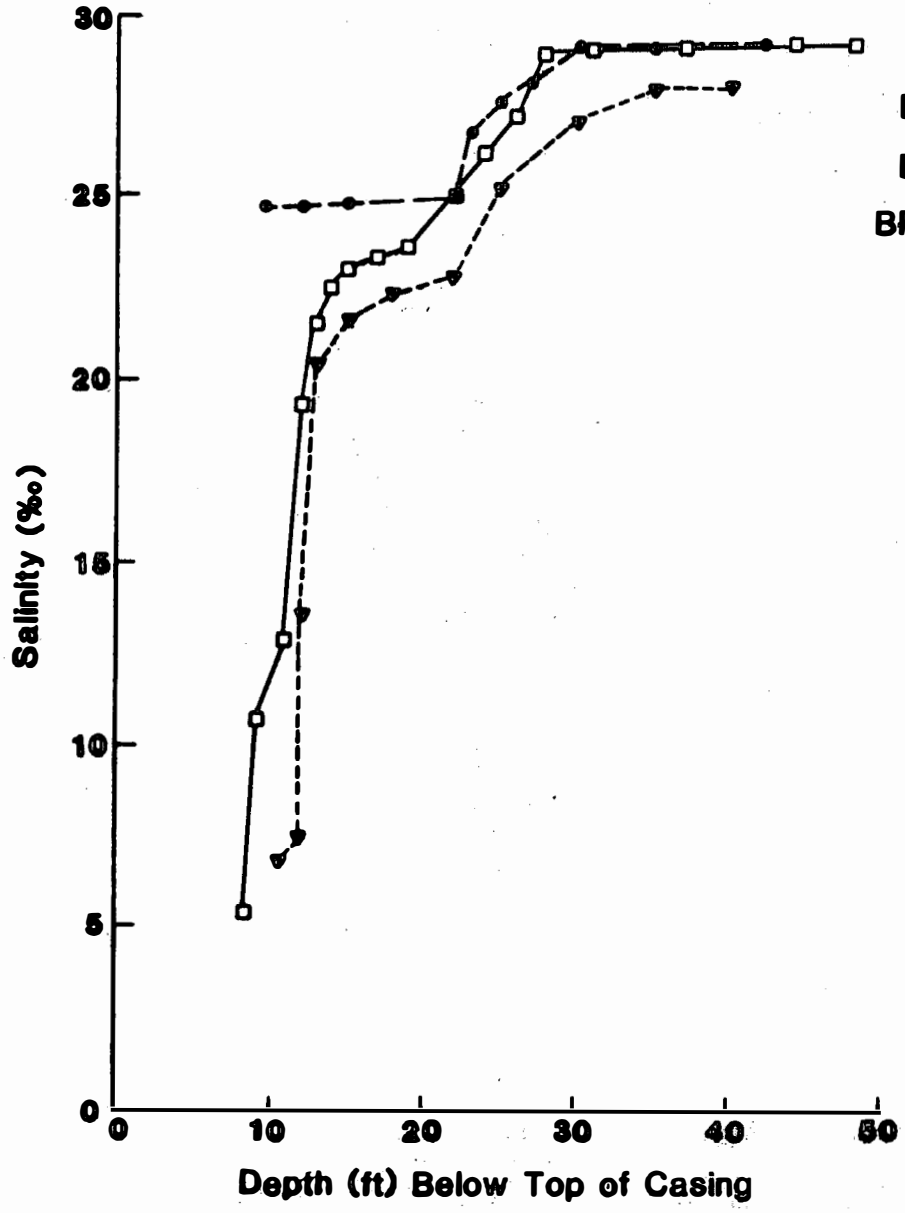
Data collected July 27, 1990

TOP OF CASING 4 FEET ABOVE MEAN SEA LEVEL

BLACKHAWK GEOSCIENCES, INC.

**SALINITY PROFILES**
**CAMPBELL INDUSTRIAL PARK**
***HASEKO (HAWAII), INC.***

PROJECT NO: 90029 Figure 4-2




BP-40 ——— 40 Feet from shore

BP-80 ——— 80 Feet from shore

BP-150 - - - - - 150 Feet from shore

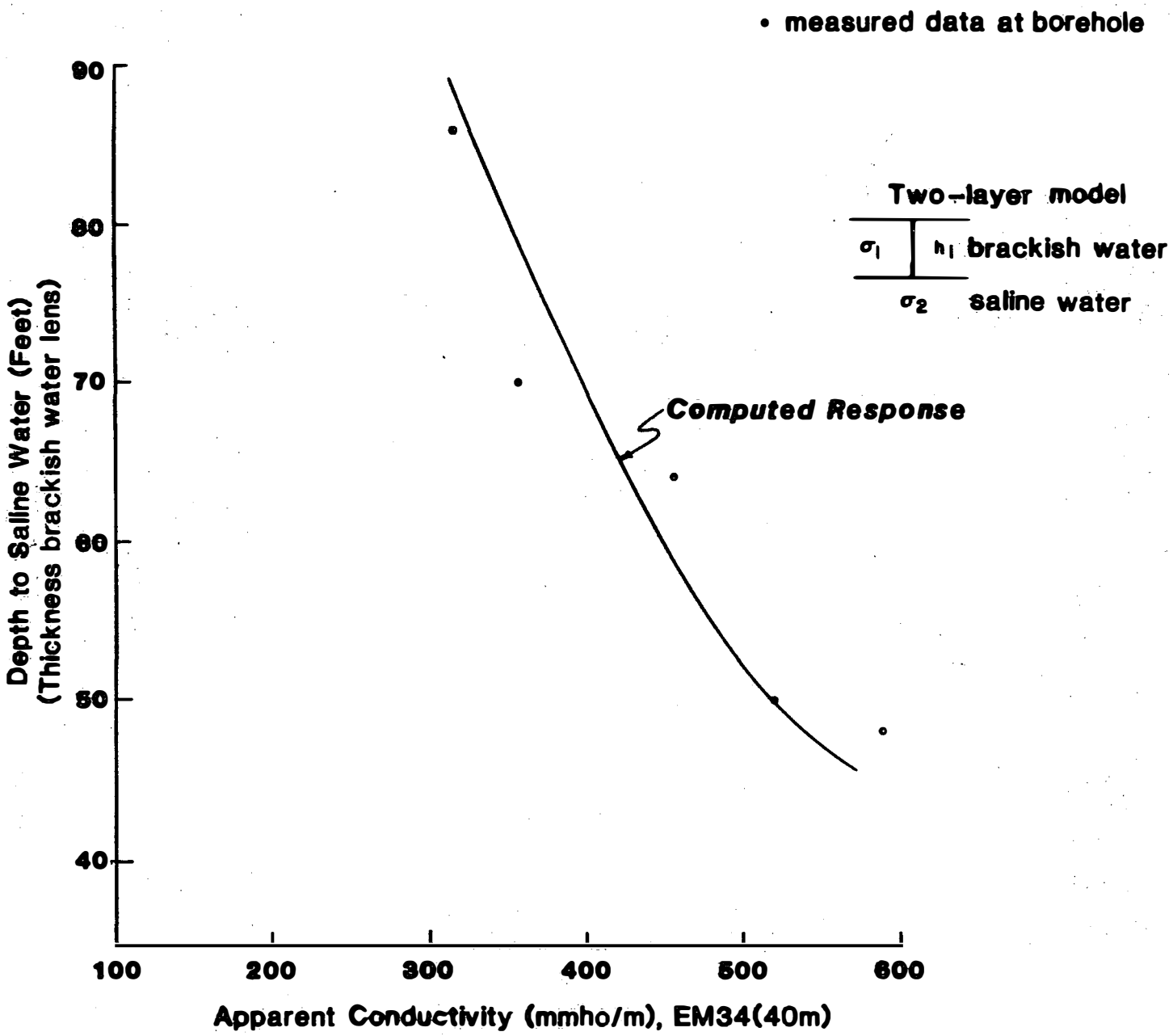
Data collected July 27, 1990

TOP OF CASING 11 FEET ABOVE MEAN SEA LEVEL

BLACKHAWK GEOSCIENCES, INC.

SALINITY PROFILES
BARBERS POINT HARBOR
*HASEKO (HAWAII), INC.*

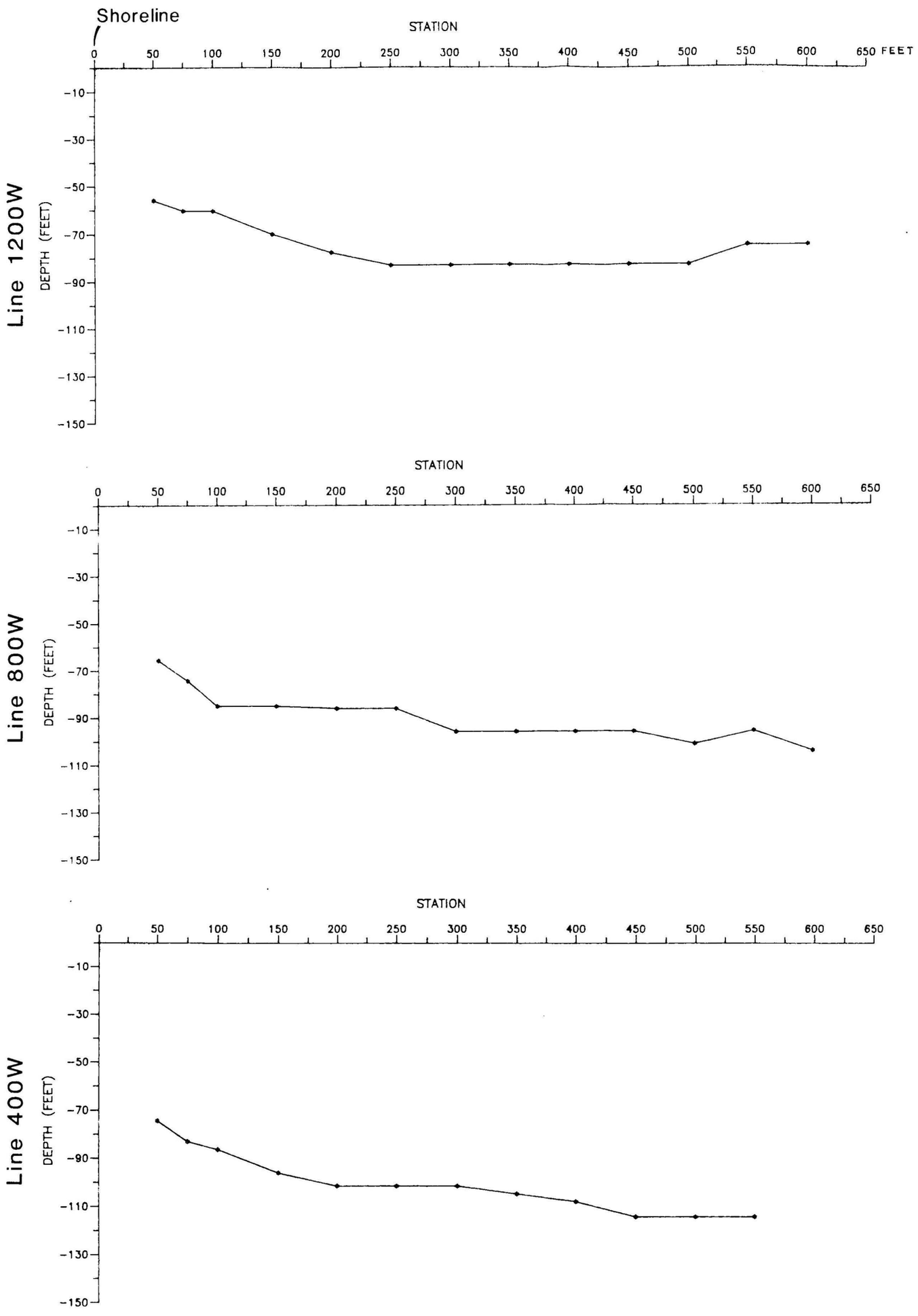
PROJECT NO: 90029 Figure 4-3




BLACKHAWK GEOSCIENCES, INC.

**INSTRUMENT (EM34) READING VERSUS BRACKISH WATER LENS THICKNESS**
***HASEKO (HAWAII), INC.***

PROJECT NO: 90029 Figure 4-4




***LEGEND***

DEPTH PROFILE – EWA MARINA

Calculated depth response for 40m EM34 coil separation data

BOREHOLE RESULTS

Brackish water lens

Saline water saturated limestone

Area of near surface high conductivity

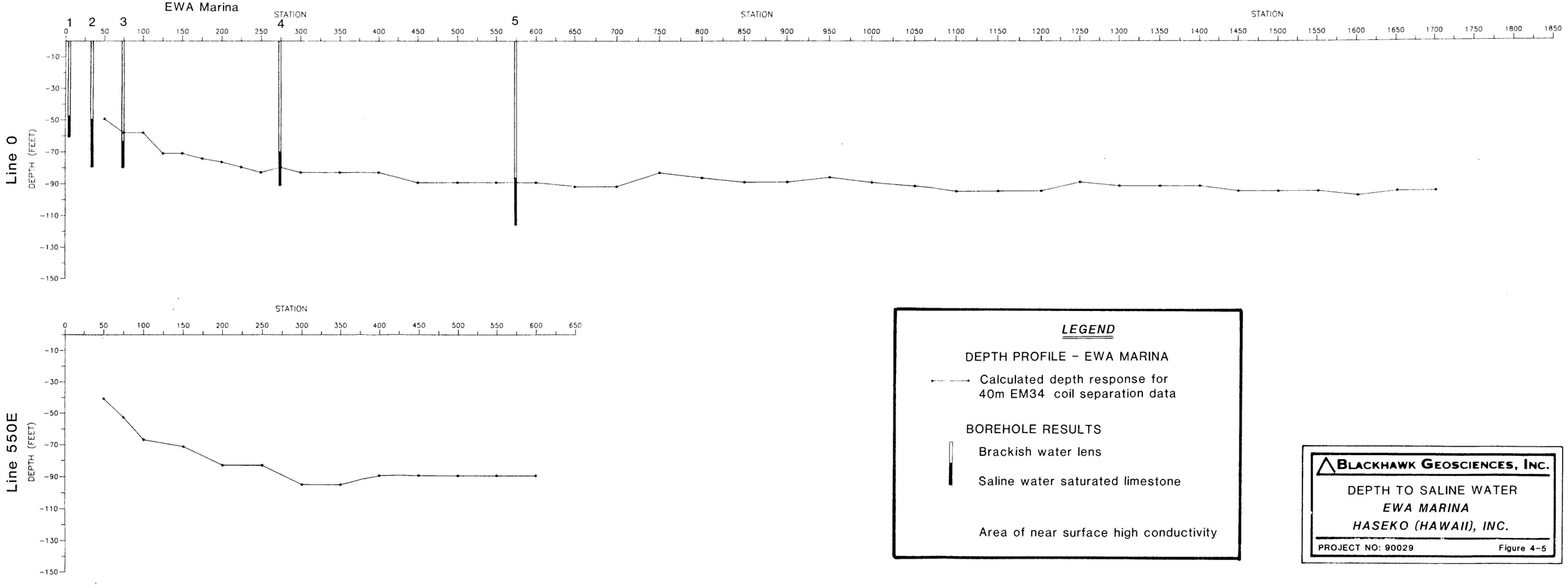
**BLACKHAWK GEOSCIENCES, INC.**

DEPTH TO SALINE WATER

*EWA MARINA*

*HASEKO (HAWAII), INC.*

PROJECT NO: 90029 Figure 4-5




***LEGEND***

DEPTH PROFILE – EWA MARINA

Calculated depth response for 40m EM34 coil separation data

BOREHOLE RESULTS

Brackish water lens

Saline water saturated limestone

Area of near surface high conductivity

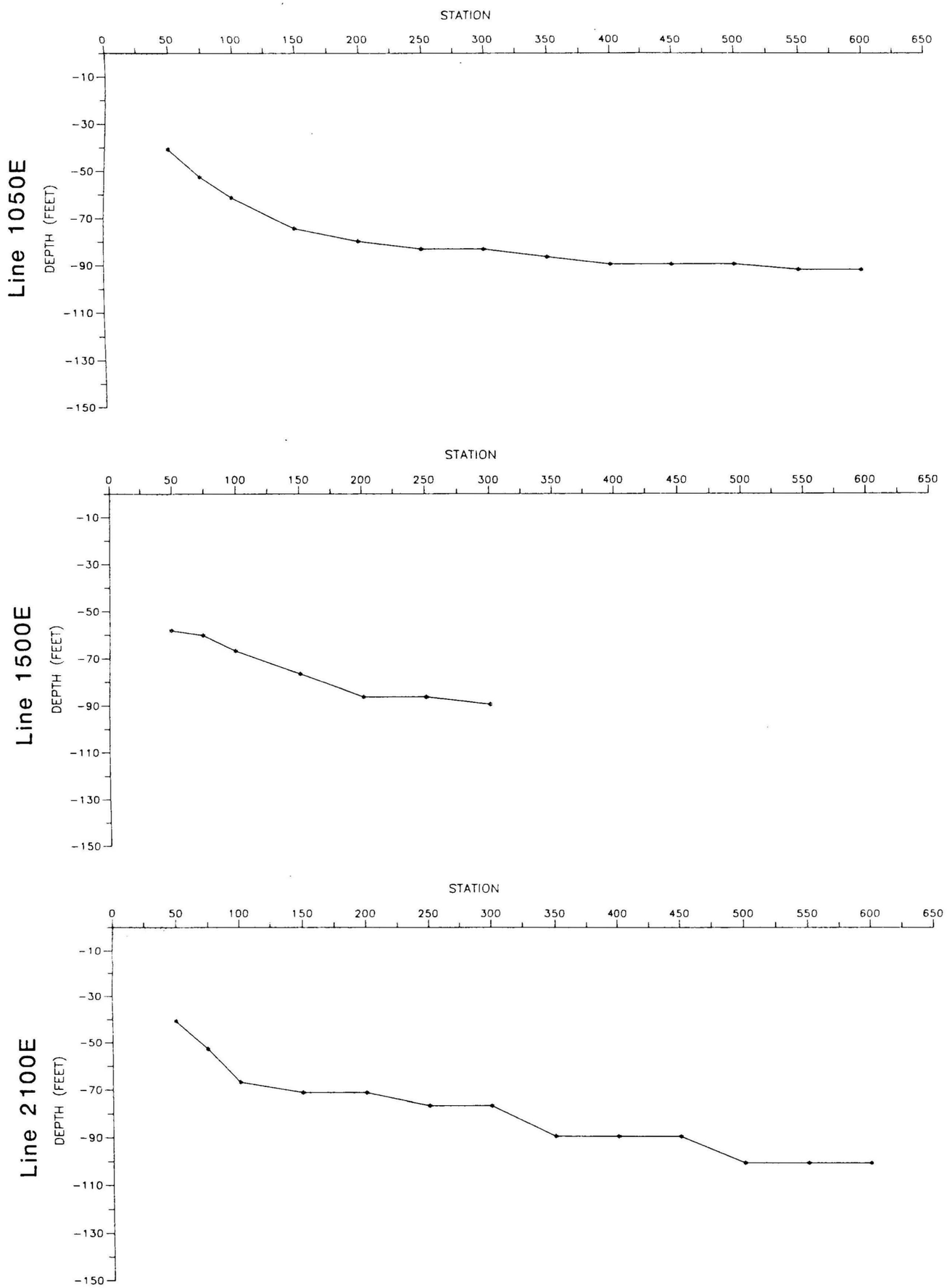
**BLACKHAWK GEOSCIENCES, INC.**

DEPTH TO SALINE WATER

*EWA MARINA*

*HASEKO (HAWAII), INC.*

PROJECT NO: 90029 Figure 4-5




***LEGEND***

DEPTH PROFILE – EWA MARINA

Calculated depth response for 40m EM34 coil separation data

BOREHOLE RESULTS

Brackish water lens

Saline water saturated limestone

Area of near surface high conductivity

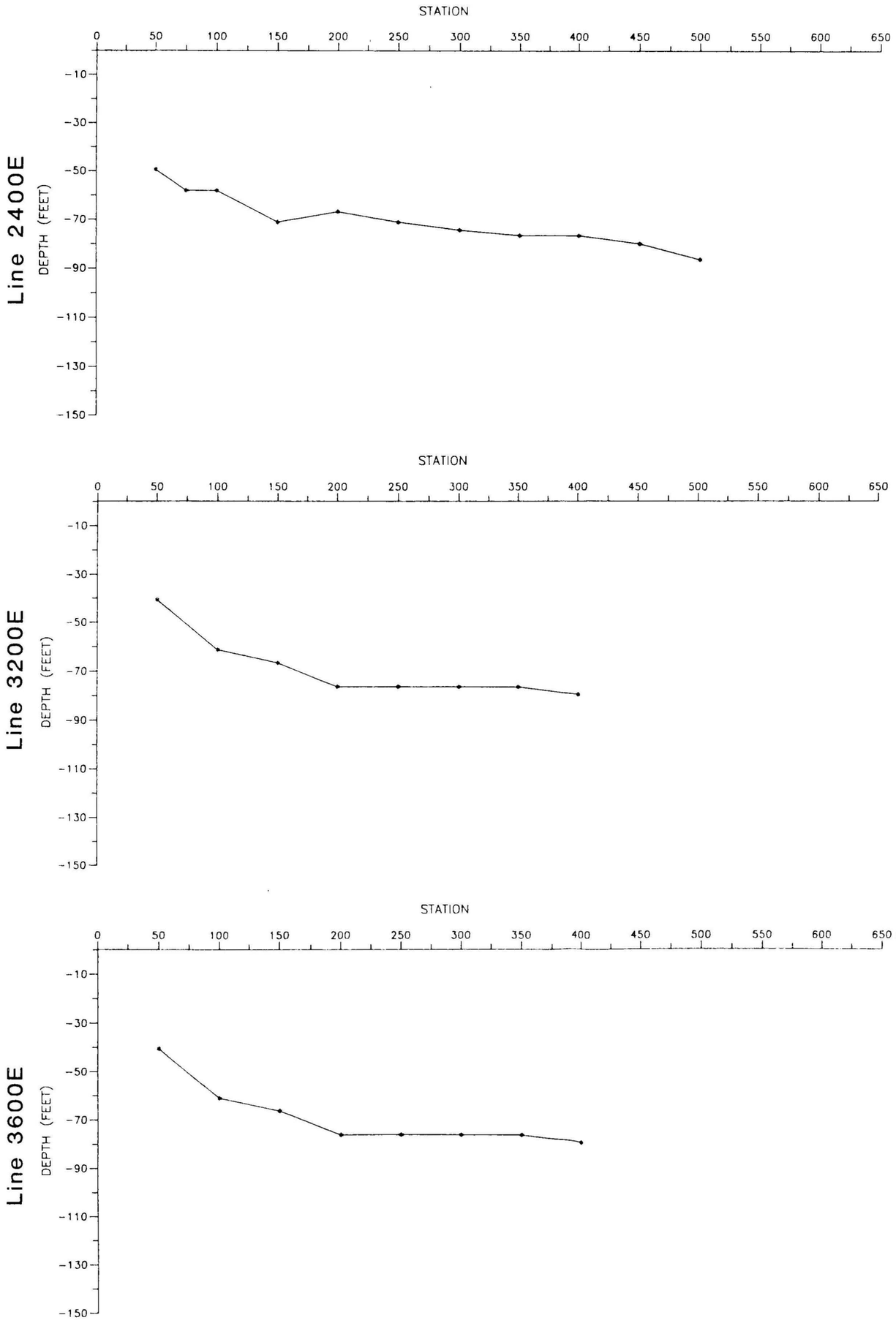
**BLACKHAWK GEOSCIENCES, INC.**

DEPTH TO SALINE WATER

*EWA MARINA*

*HASEKO (HAWAII), INC.*

PROJECT NO: 90029 Figure 4-5




***LEGEND***

DEPTH PROFILE - EWA MARINA

Calculated depth response for 40m EM34 coil separation data

BOREHOLE RESULTS

Brackish water lens

Saline water saturated limestone

Area of near surface high conductivity

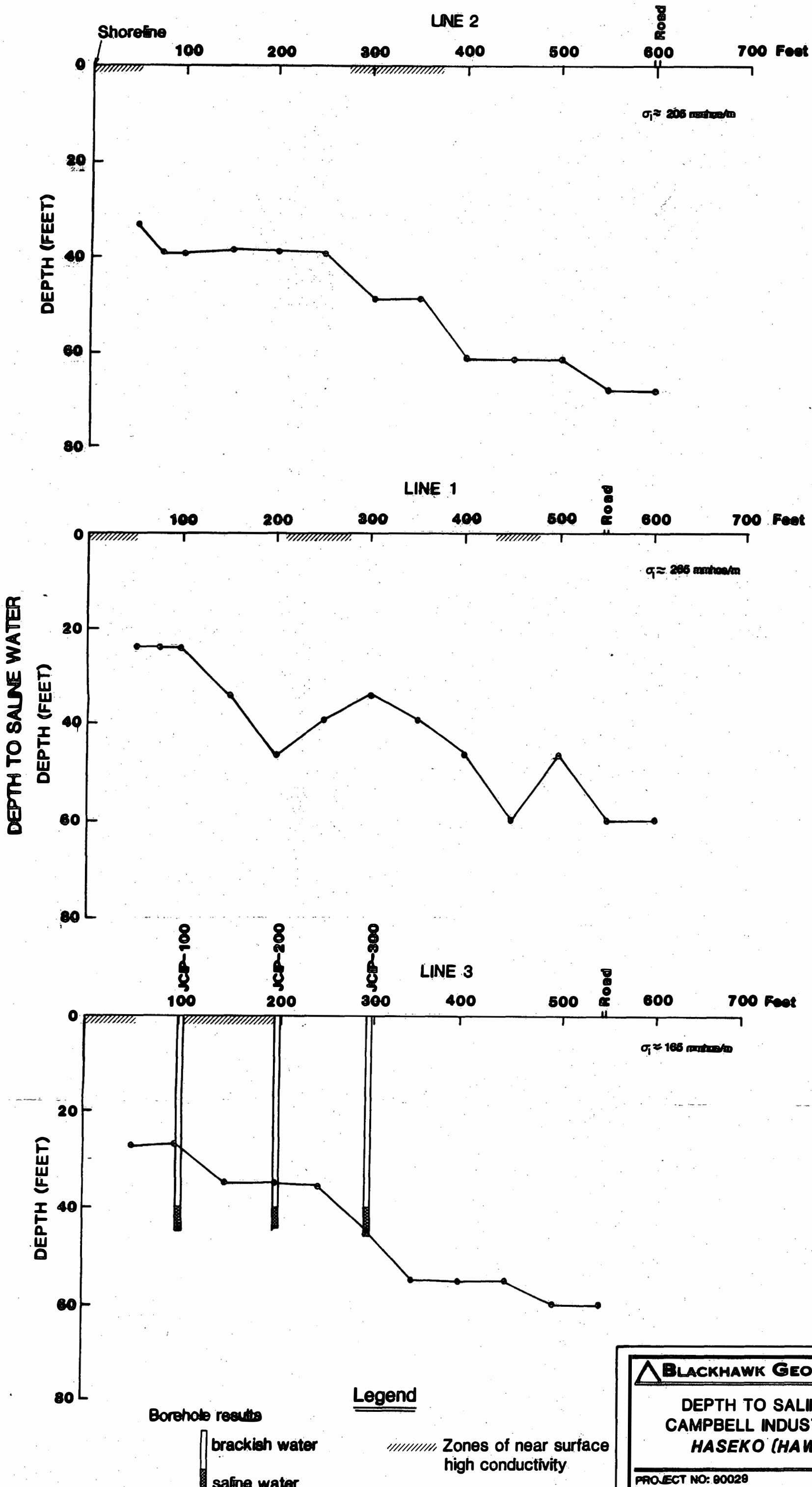
**BLACKHAWK GEOSCIENCES, INC.**

DEPTH TO SALINE WATER

*EWA MARINA*

*HASEKO (HAWAII), INC.*

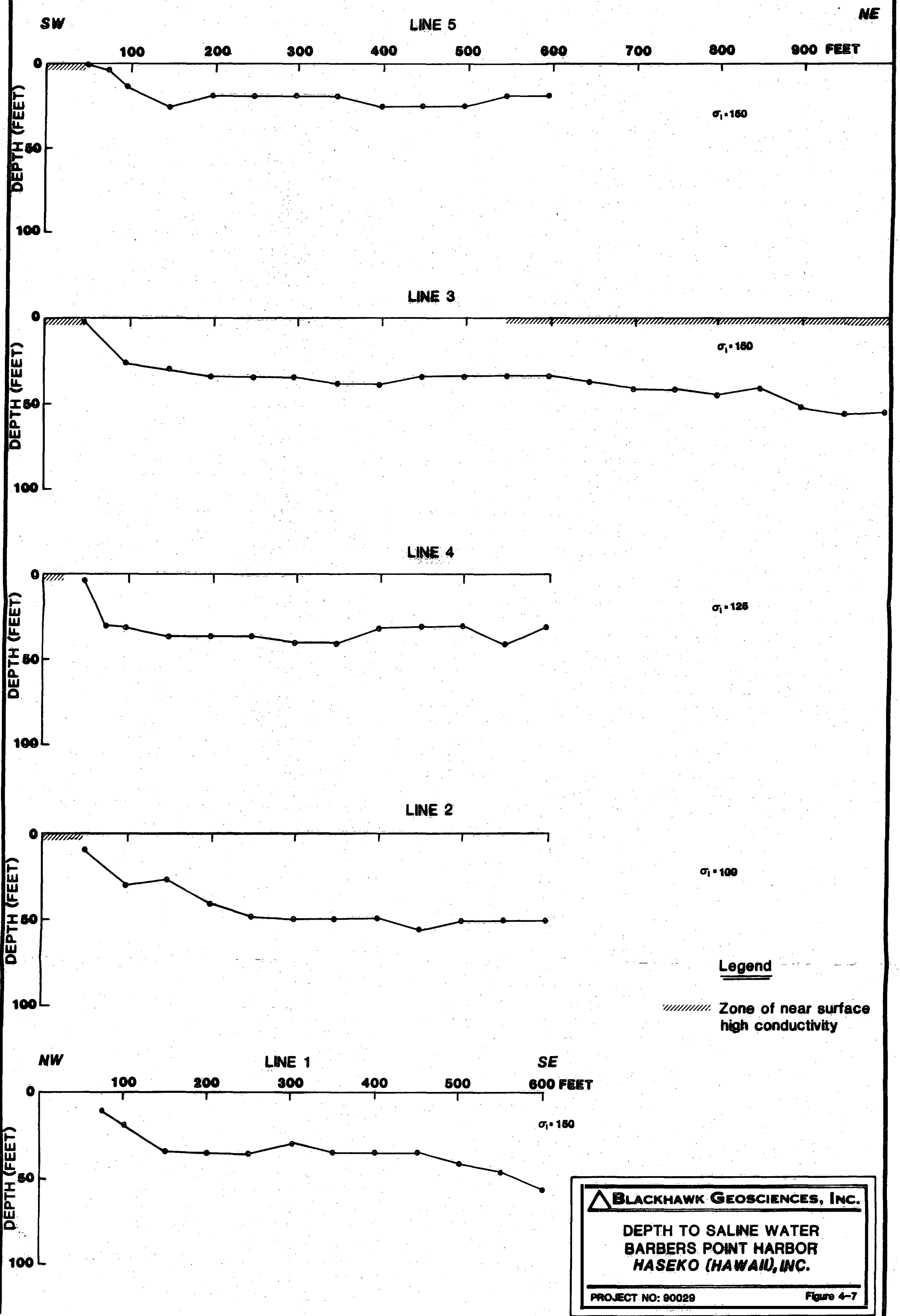
PROJECT NO: 90029 Figure 4-5




**BLACKHAWK GEOSCIENCES, INC.**

DEPTH TO SALINE WATER
CAMPBELL INDUSTRIAL PARK
*HASEKO (HAWAII), INC.*

PROJECT NO: 90029 Figure 4-6




**BLACKHAWK GEOSCIENCES, INC.**

DEPTH TO SALINE WATER
BARBERS POINT HARBOR
*HASEKO (HAWAII), INC.*

PROJECT NO: 90029 Figure 4-7

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

The EM-34 data have been used to generate depth to saline water profiles by using correlations with nearby borehole salinity logs.

At Ewa Marina the depth to saline water is typically between 80 and 100 ft at distances greater than 300 ft from the shoreline. Near the shoreline the depth to saline water is shallow and rapidly increases with distance away from the shoreline. There is good agreement between the borehole results and EM-34 calculated depth to saline water.

At Campbell Industrial Park the depth to saline water calculated from the EM-34 data generally shows a smoothly varying increase from the shoreline to the end of the lines. The depths vary from about 20 to 30 ft near the shore to about 60 to 70 ft at the end of the line. The correlation between the boreholes and EM-34 data is influenced by averaging effects of surface geophysics and near surface pockets of high salinity.

At the Barbers Point Harbor the depth to saline water derived from the EM-34 data show a pattern similar to Ewa Marina, i.e., a rapid increase in depth near the shoreline, with a leveling out of the depth at distances greater than about 200 ft from the shore. However, the maximum depth to saline water at Barbers Point Harbor (about 50 ft) is much less than at Ewa Marina.

A qualitative comparison of salinities in the brackish water layer can be obtained by comparing the EM-34 data at 20 m separation for the three areas. In Table 5-1 typical values for the EM-34 data at 20 m for the areas are given.

**Table 5-1. Typical EM-34 (20 m) data values**

| Area | Data Range (mmhos/m) |
|---|---|
| Ewa Marina | 125 to 250 |
| Campbell Industrial Park | 200 to 350 |
| Barbers Point Harbor | 200 to 325 |

The comparison in Table 5-1 shows that the brackish water layer should be less saline at Ewa Marina than at the other two areas. This is confirmed in the borehole salinity profiles for the three areas (Figs. 4-1, 4-2 and 4-3). Using this same qualitative comparison, the salinity of the brackish water layer at Campbell Industrial Park and Barbers Point Harbor should be similar. However, the borehole salinity profiles at Barbers Point Harbor show higher salinities in the near surface than at Campbell Industrial Park. If this comparison is valid it suggests that the boreholes at Barbers Point Harbor may have been

placed in an area not representative of the salinity distribution around the rest of the Harbor.

Accuracies of determining the depth to saline water along the profiles at Ewa Marina is expected to be approximately ± 5 ft. At Barbers Point Harbor and Campbell Industrial Park the accuracies are expected to be somewhat less because an experimental relationship between borehole salinity profiles and EM-34 data could not be directly obtained.

**ATTACHMENT A**

# GEOPHYSICAL SURVEYS WITH FDEM METHODS EWA MARINA, CAMPBELL INDUSTRIAL PARK AND BARBERS POINT HARBOR OAHU, HAWAII

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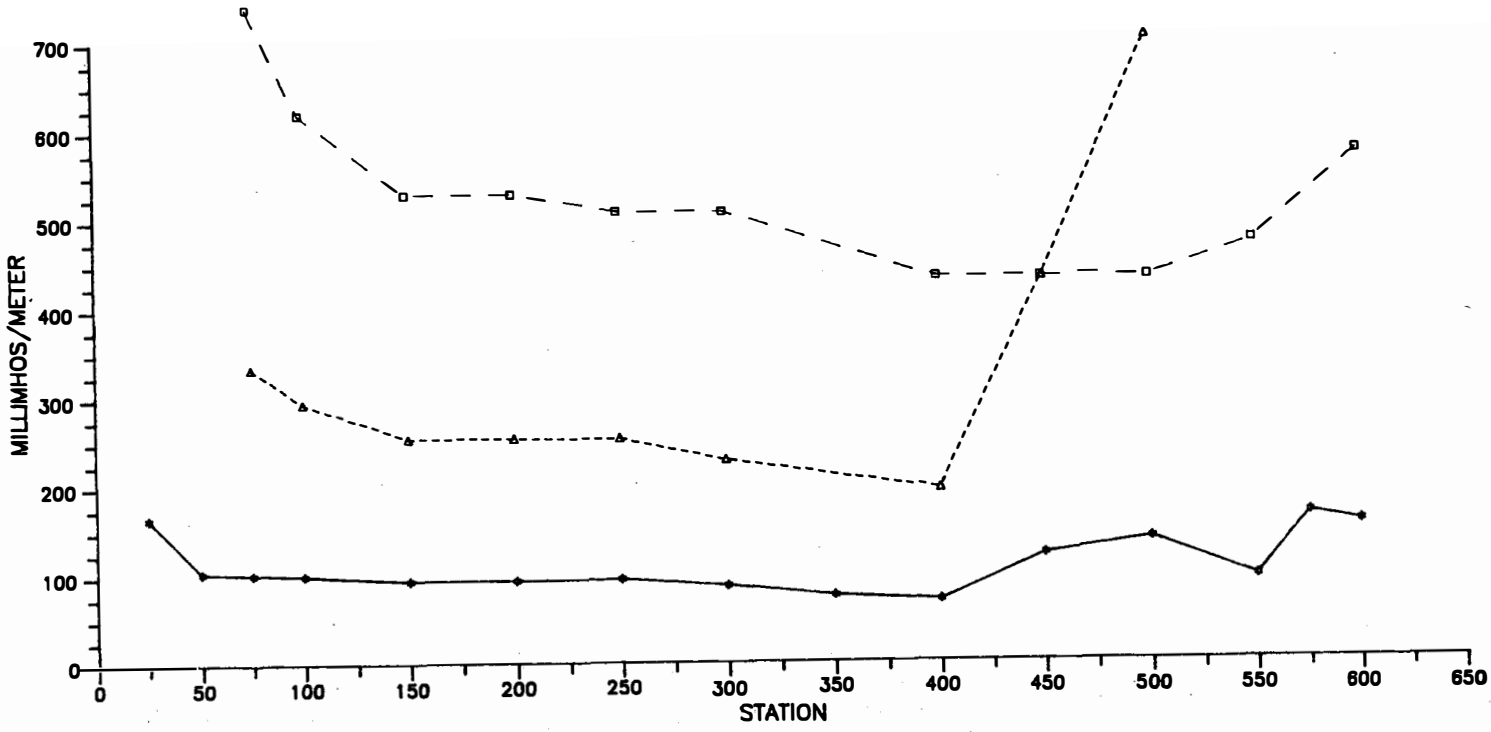
August 8, 1990

(Our Job #90029)




40m Coil Separation

20m Coil Separation

10m Coil Separation

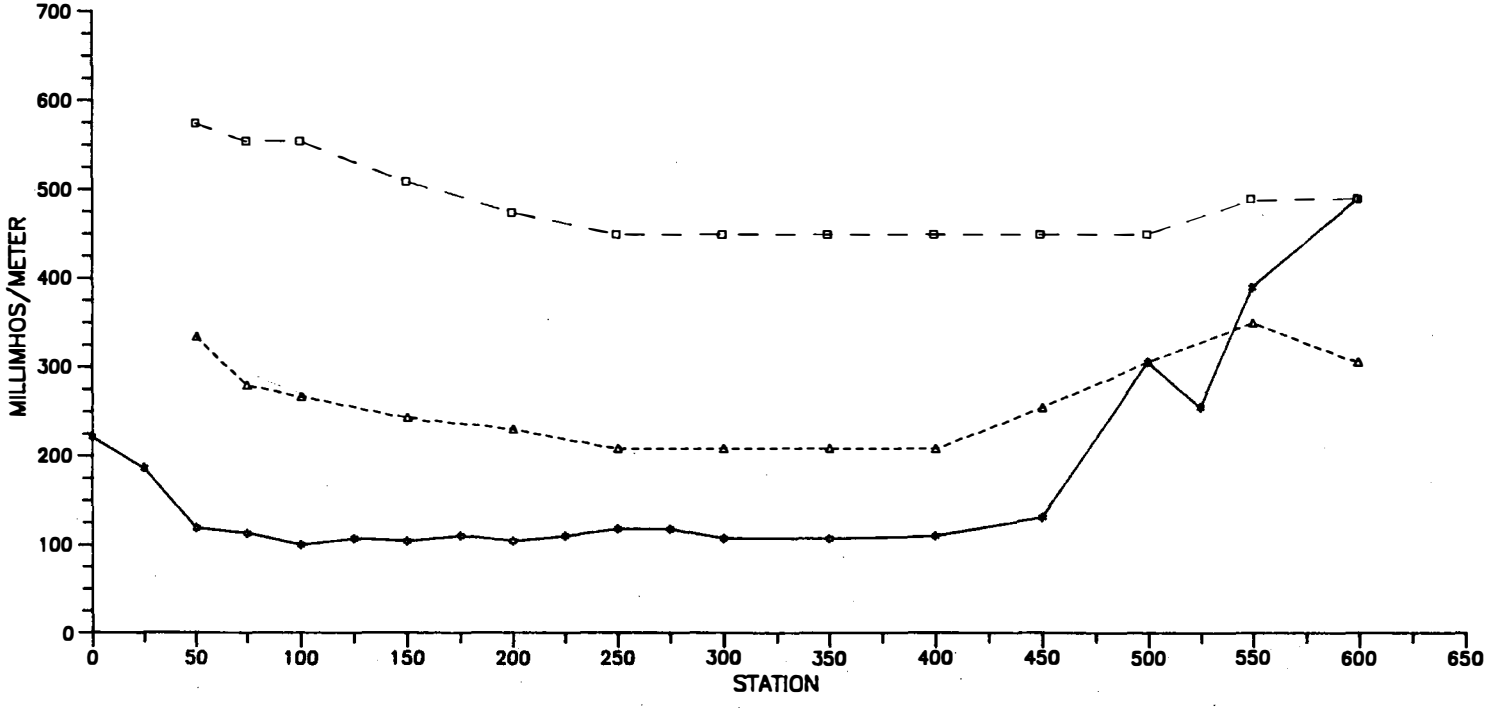
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE 1400W
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

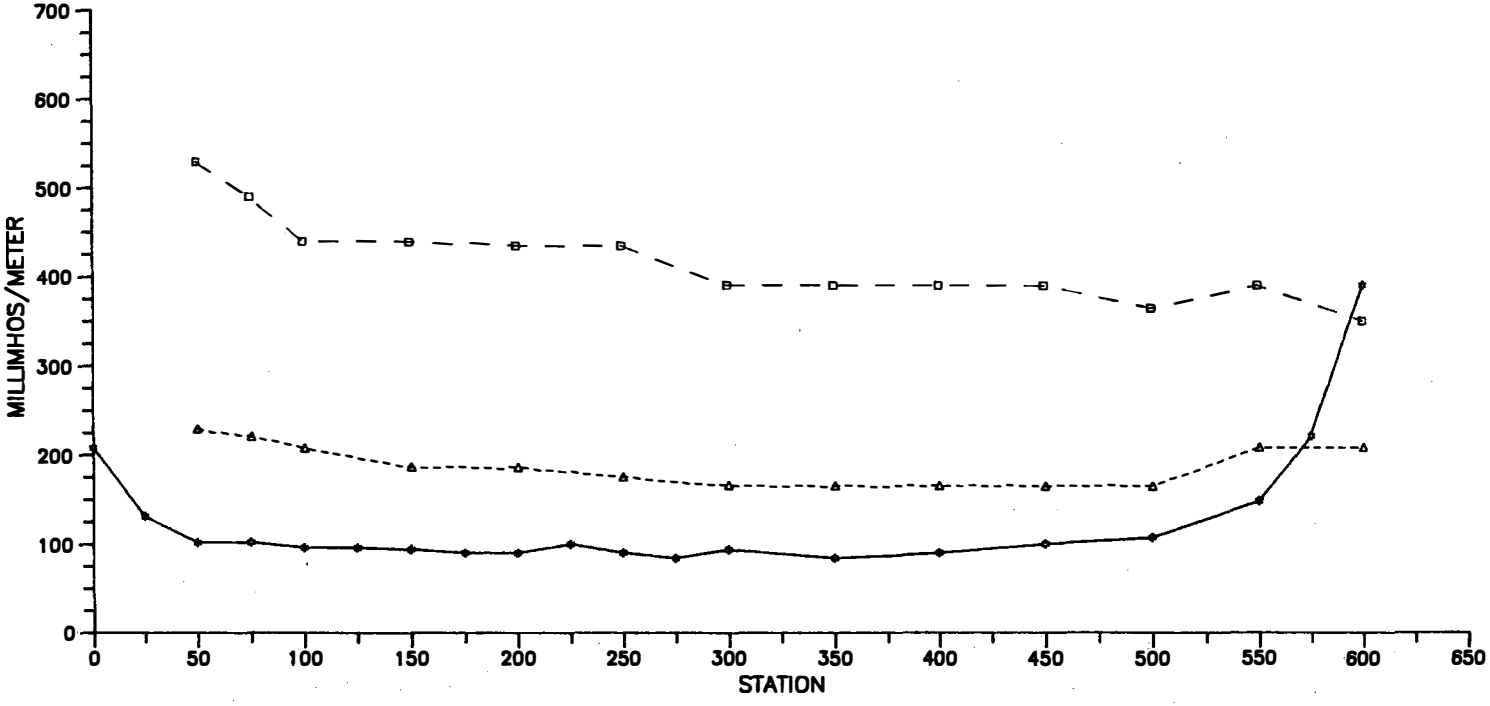
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE 1200W
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

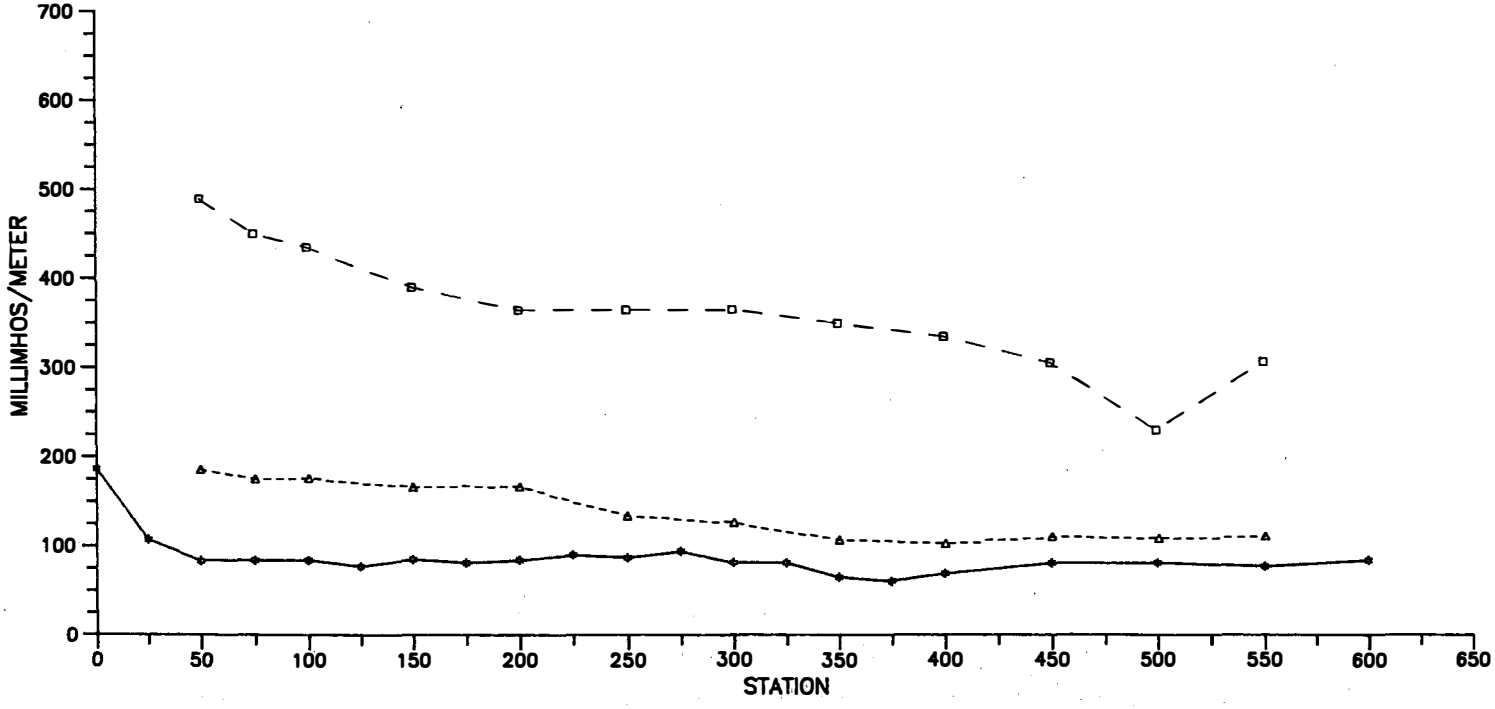
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE 800W
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

0 50 100

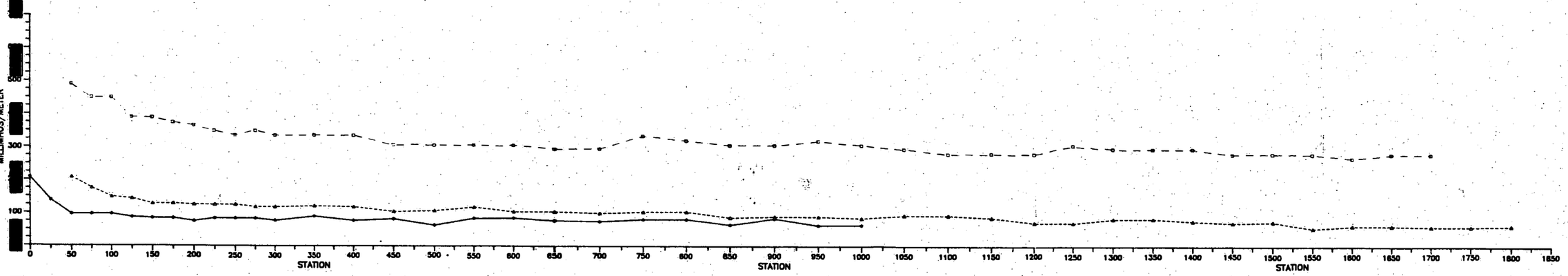
HORIZONTAL SCALE (feet)

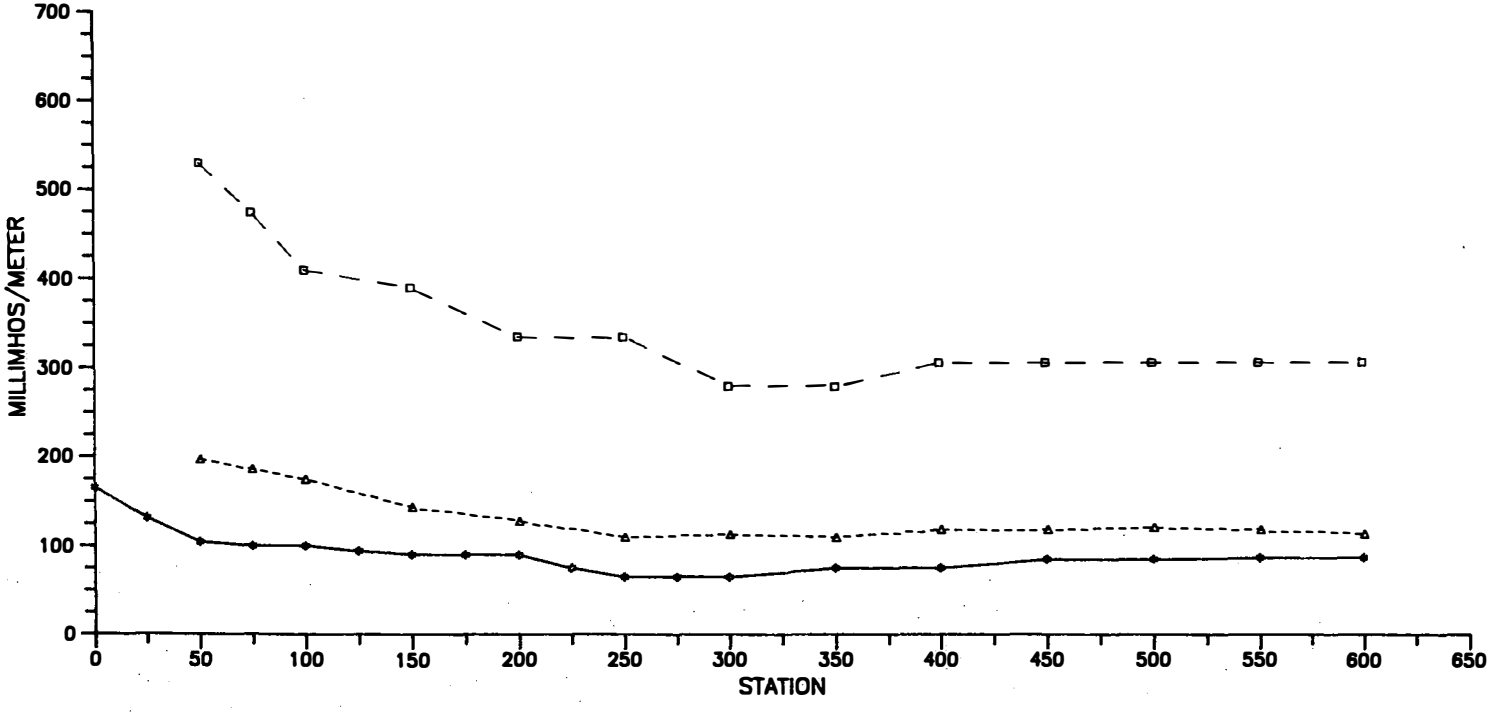
**BLACKHAWK GEOSCIENCES, INC.**

EM34 SURVEY
LINE 400W

*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029


MILLIMHOS/METER
500
300
100
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850
STATION
STATION
STATION
40m Coil Separation
20m Coil Separation
10m Coil Separation
0 50 100
HORIZONTAL SCALE (feet)
BLACKHAWK GEOSCIENCES, INC.
EM34 SURVEY
LINE 0
HASEKO (HAWAII), INC.
EWA Marina
PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

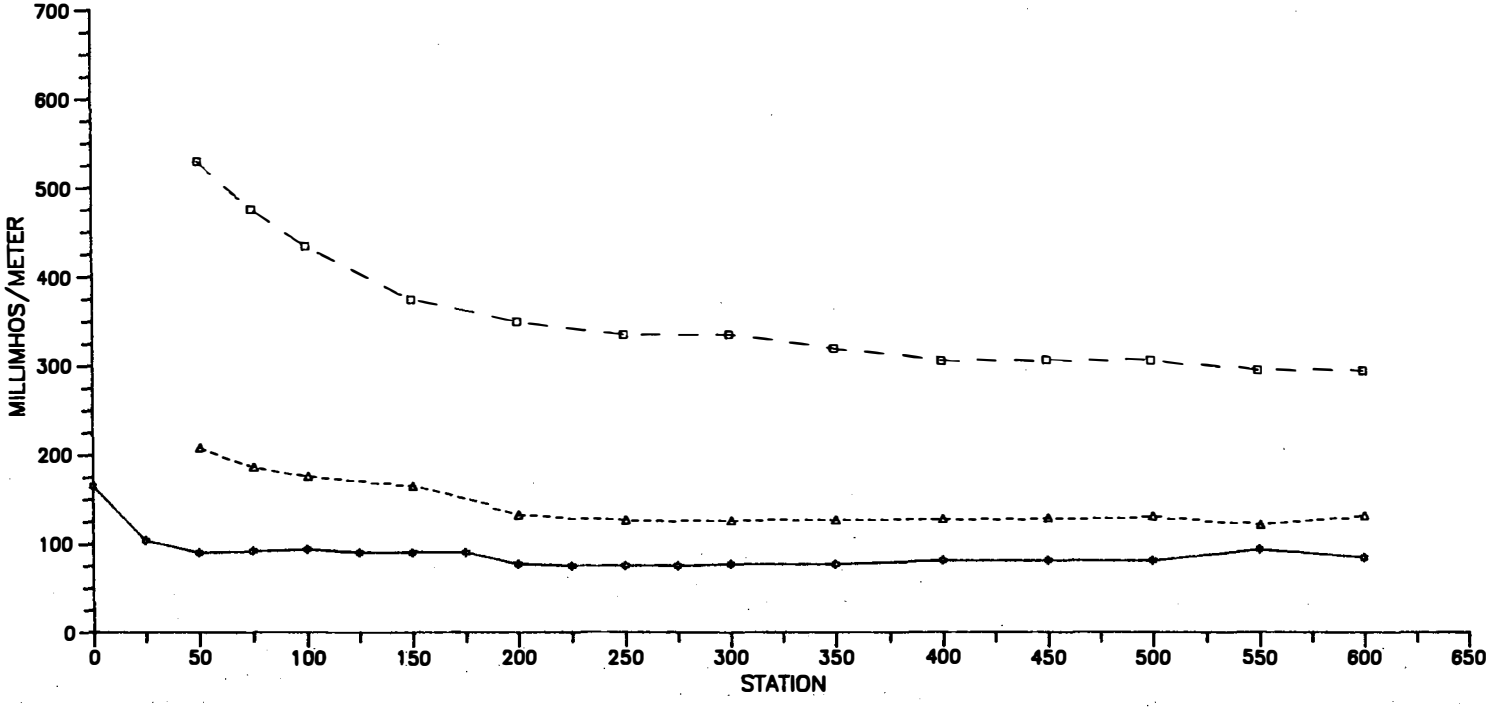
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE 550E
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

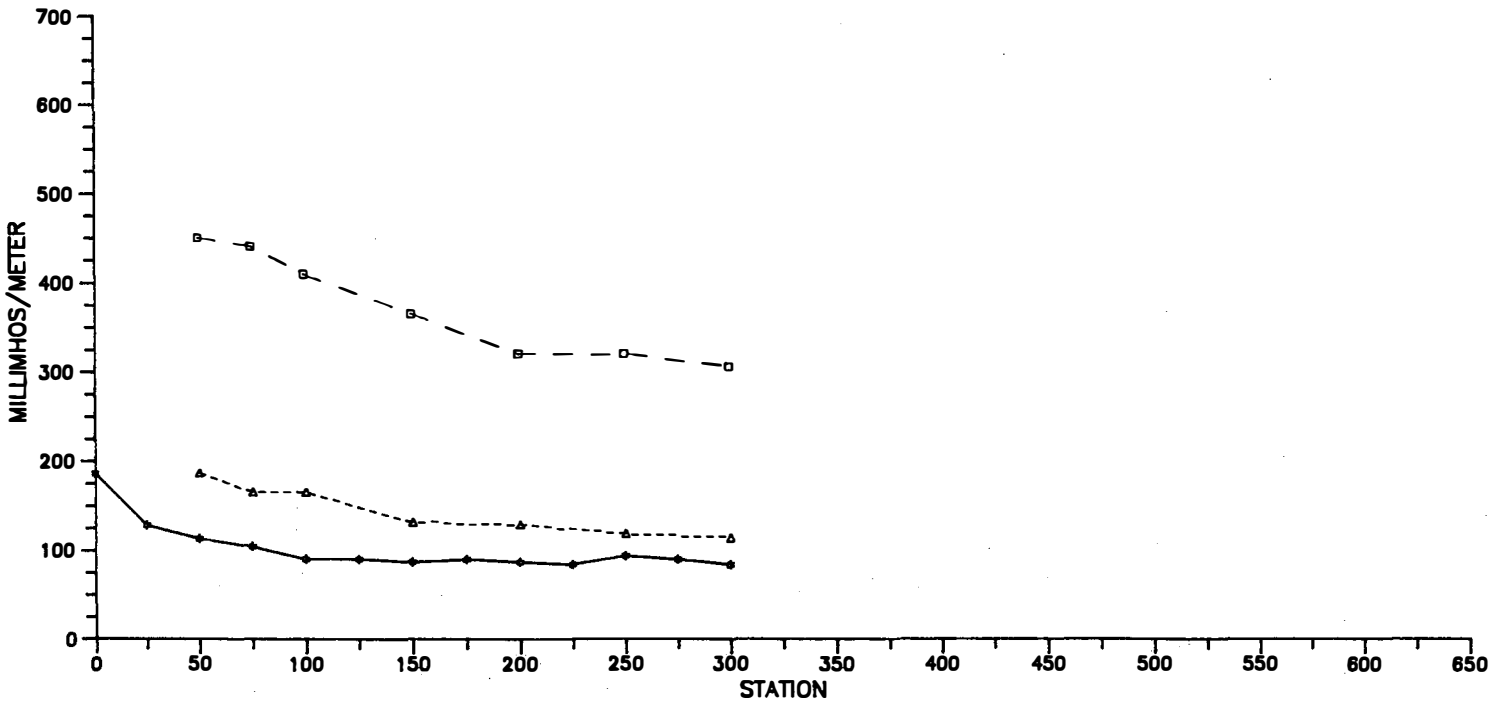
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE 1050E
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

0 50 100

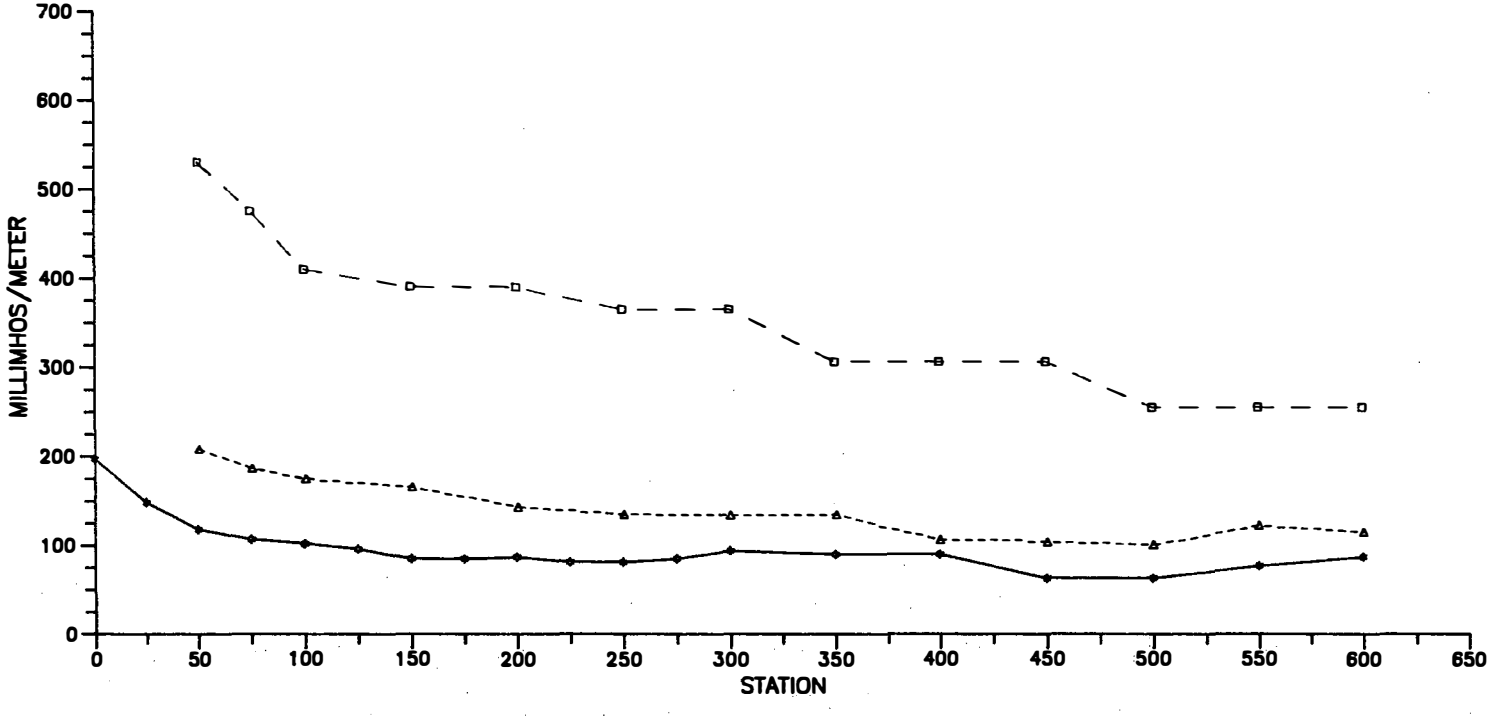
HORIZONTAL SCALE (feet)

**BLACKHAWK GEOSCIENCES, INC.**

EM34 SURVEY
LINE 1500E

*HASEKO (HAWAII), INC.*
*EWA Marina*

**PROJECT NO.: 90029**




40m Coil Separation

20m Coil Separation

10m Coil Separation

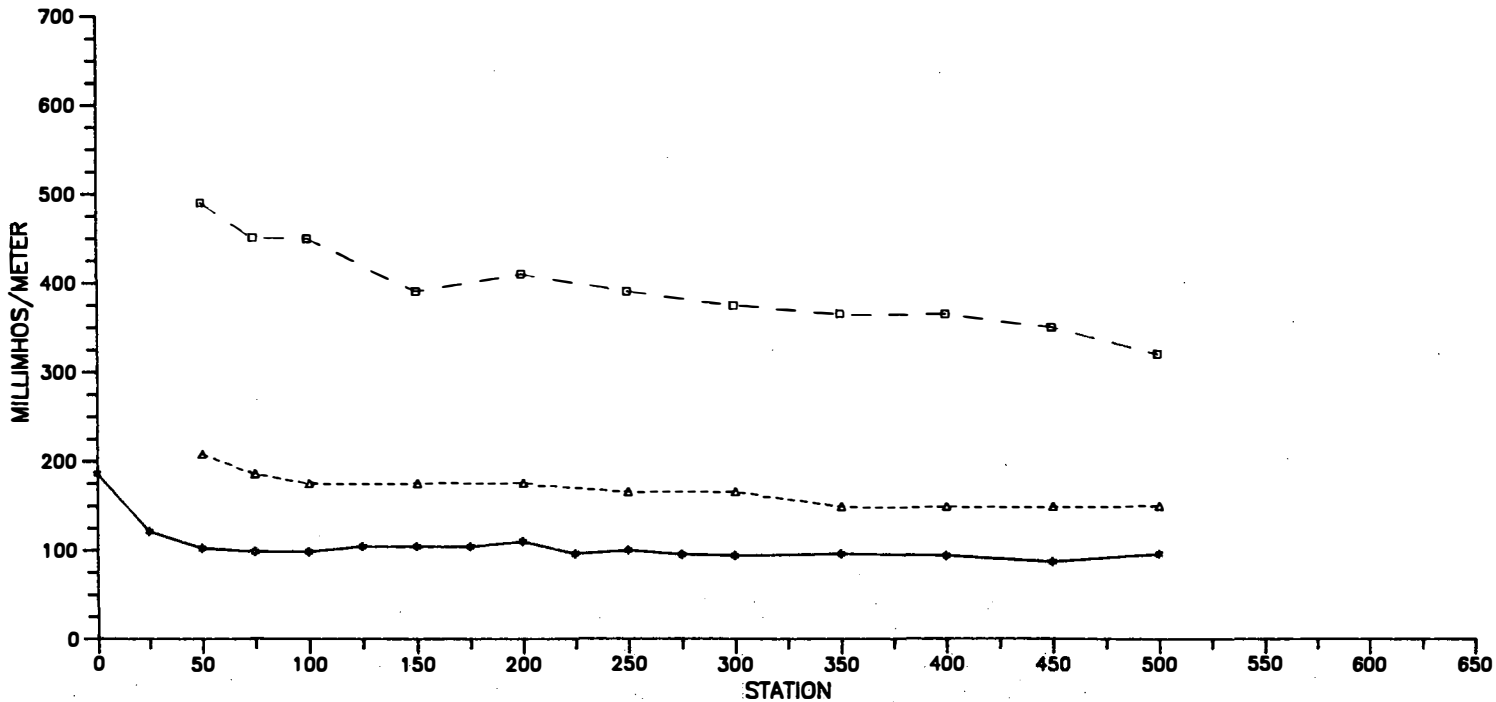
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE 2100E
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

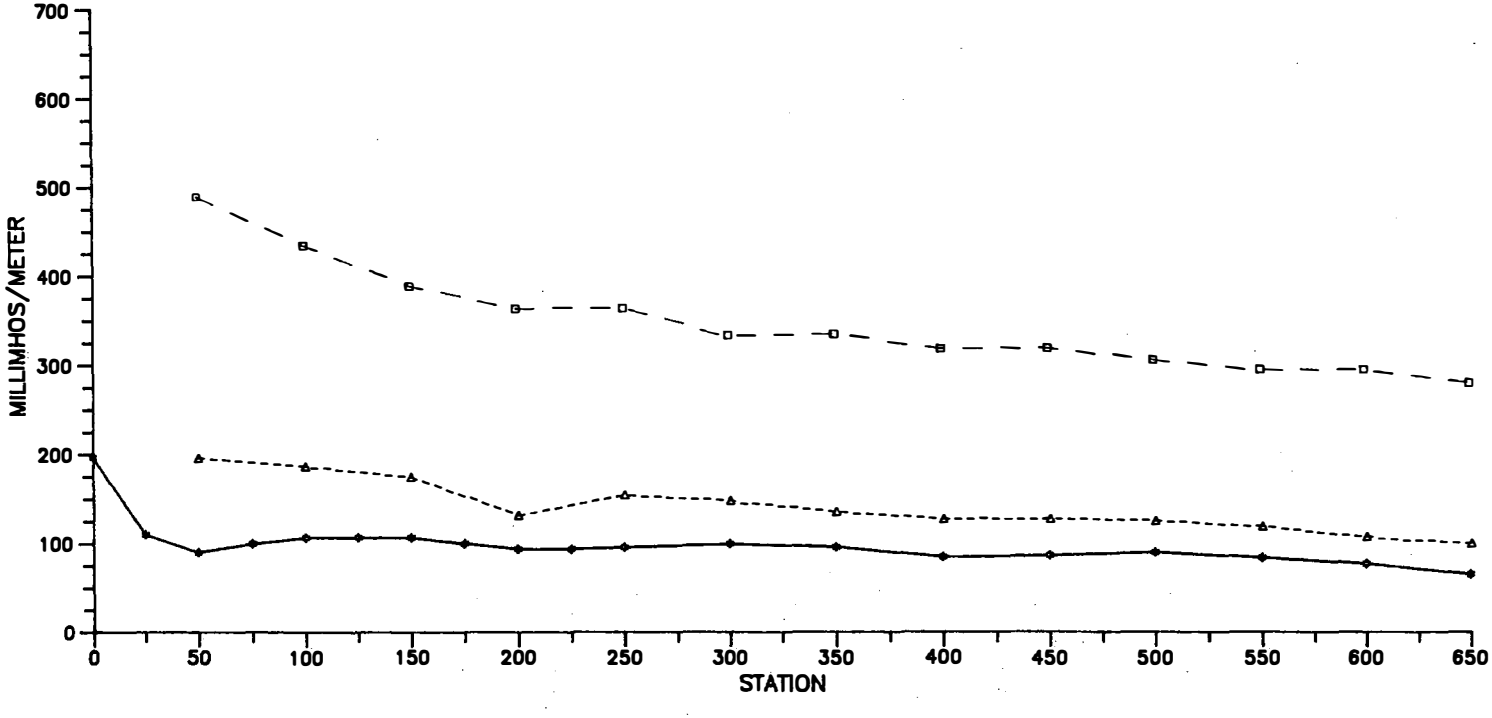
0 50 100

HORIZONTAL SCALE (feet)

**BLACKHAWK GEOSCIENCES, INC.**

EM34 SURVEY
LINE 2400E
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

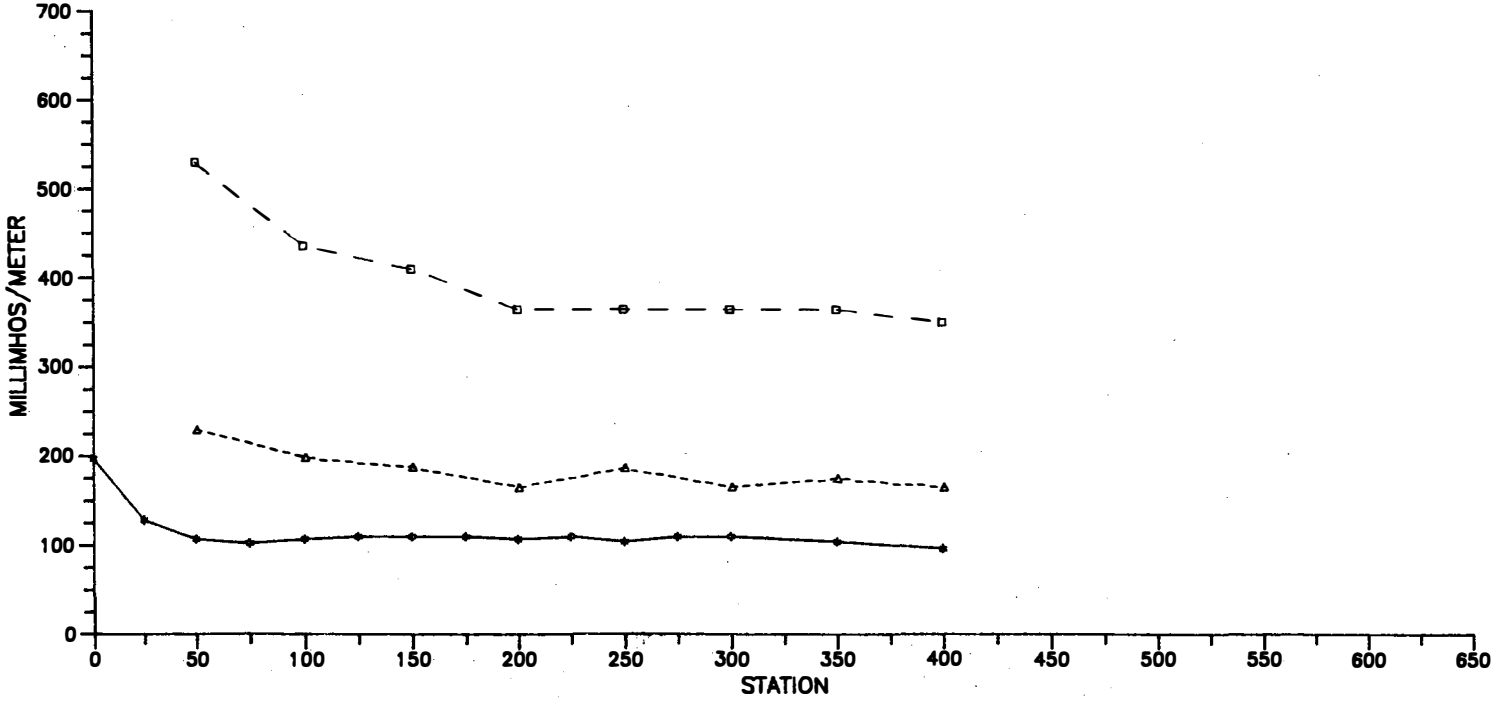
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE 3200E
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

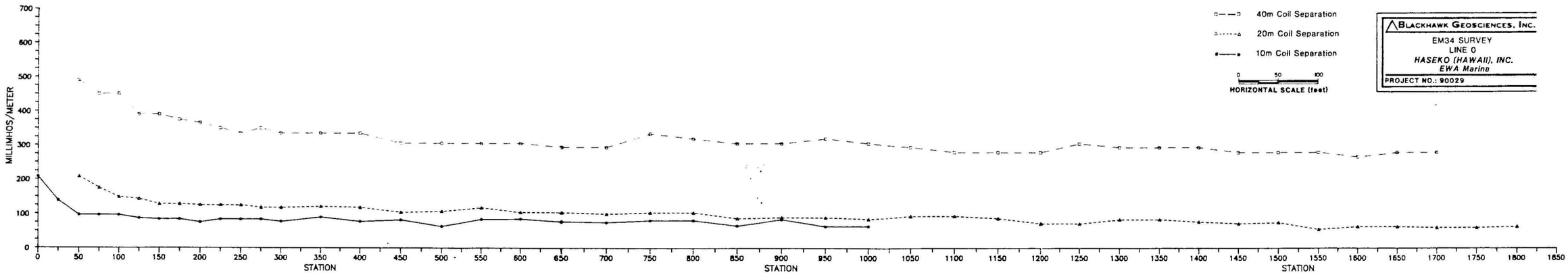
0 50 100

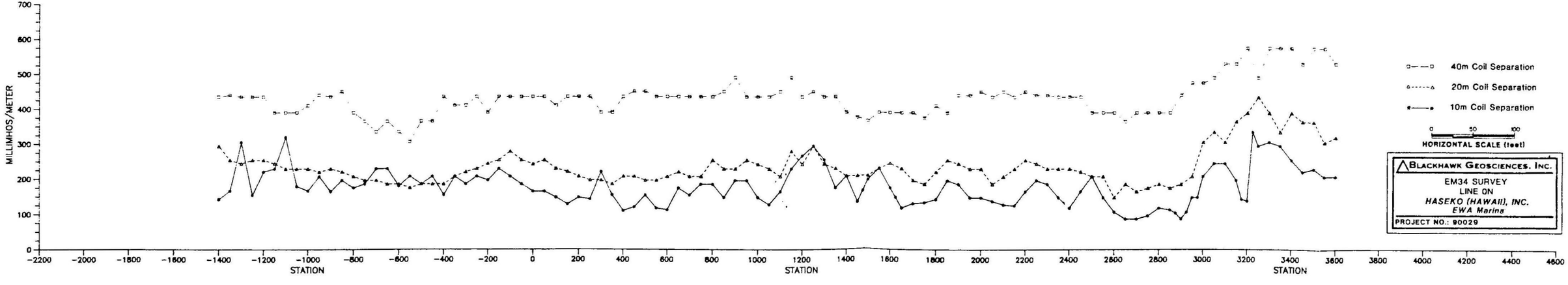
HORIZONTAL SCALE (feet)

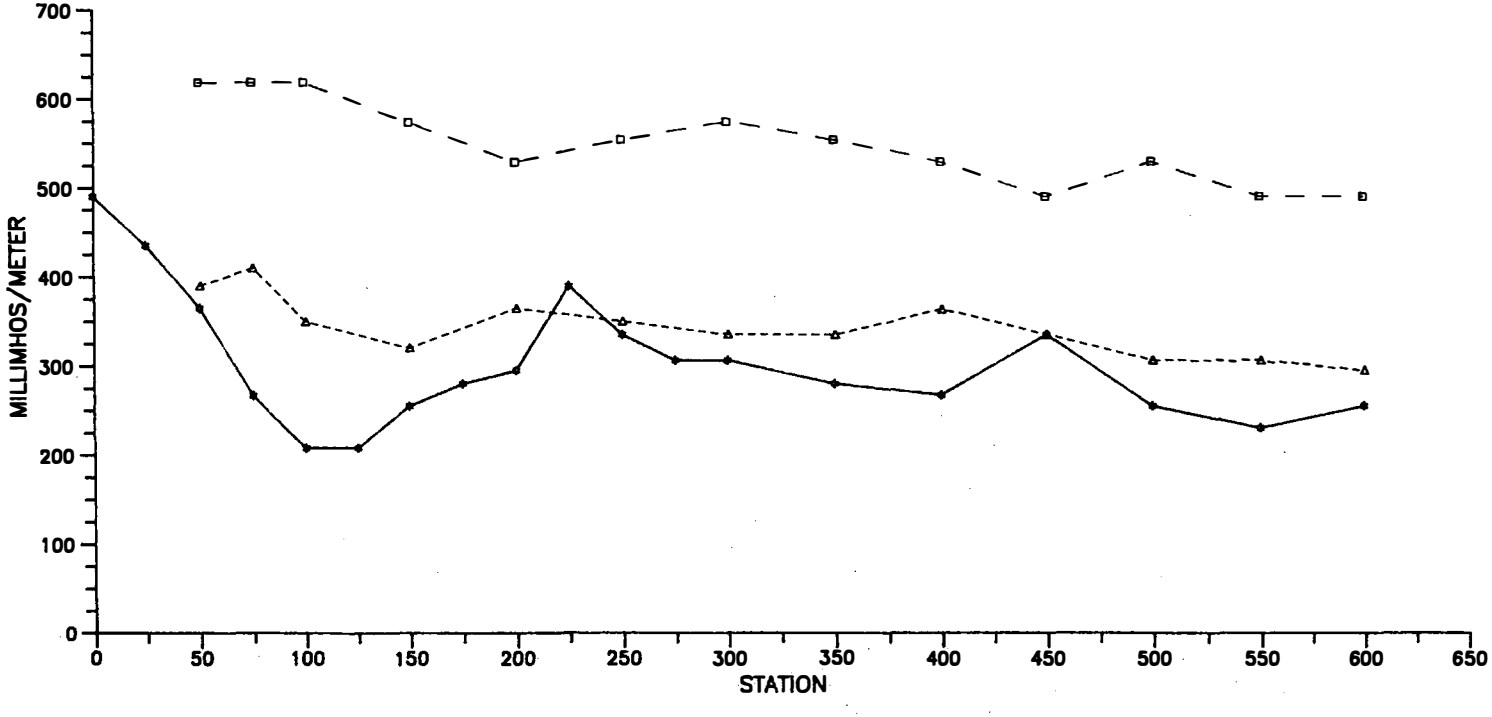
**BLACKHAWK GEOSCIENCES, INC.**

EM34 SURVEY
LINE 3600E
*HASEKO (HAWAII), INC.*
*EWA Marina*

PROJECT NO.: 90029


MILLIMHOS/METER
700
600
500
400
300
200
100
0
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850
STATION
STATION
STATION
40m Coil Separation
20m Coil Separation
10m Coil Separation
0 50 100
HORIZONTAL SCALE (feet)
BLACKHAWK GEOSCIENCES, INC.
EM34 SURVEY
LINE 0
HASEKO (HAWAII), INC.
EWA Marina
PROJECT NO.: 90029


MILLIMHOS/METER
700
600
500
400
300
200
100
0
-2200 -2000 -1800 -1600 -1400 -1200 -1000 -800 -600 -400 -200 0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000 4200 4400 4600
STATION
STATION
STATION
40m Coil Separation
20m Coil Separation
10m Coil Separation
0 50 100
HORIZONTAL SCALE (feet)
BLACKHAWK GEOSCIENCES, INC.
EM34 SURVEY
LINE 0N
HASEKO (HAWAII), INC.
EWA Marina
PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

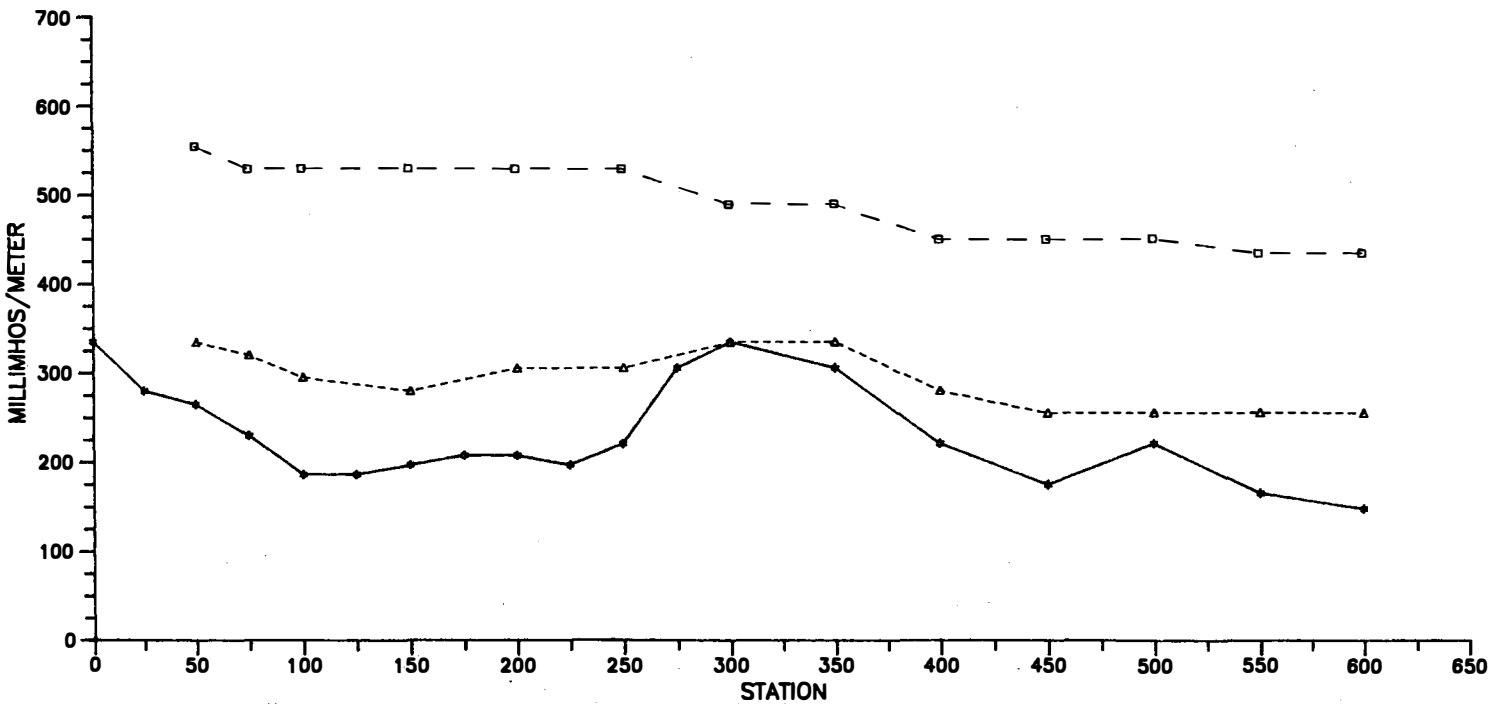
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE C1N
*HASEKO (HAWAII), INC.*
*CAMPBELL INDUSTRIAL PARK*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

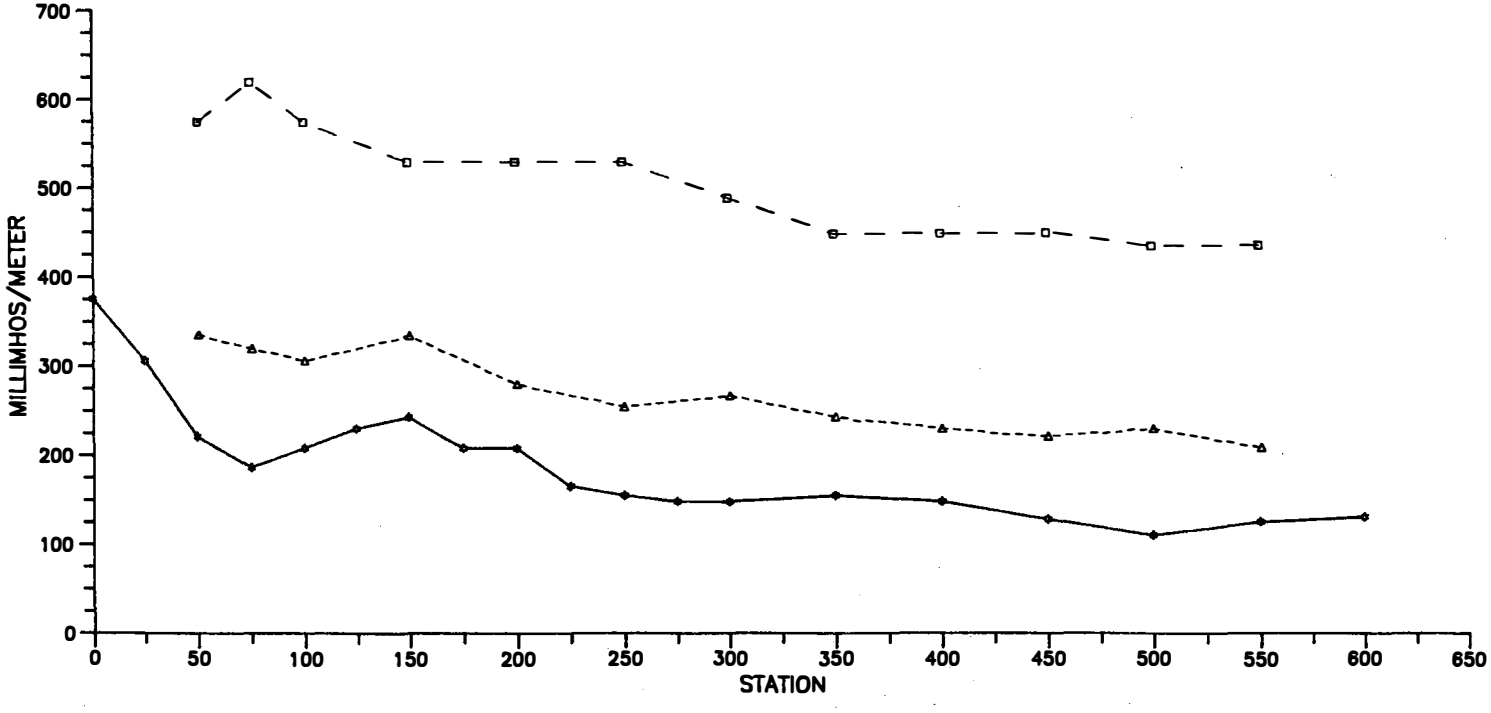
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE C2N
*HASEKO (HAWAII), INC.*
*CAMPBELL INDUSTRIAL PARK*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

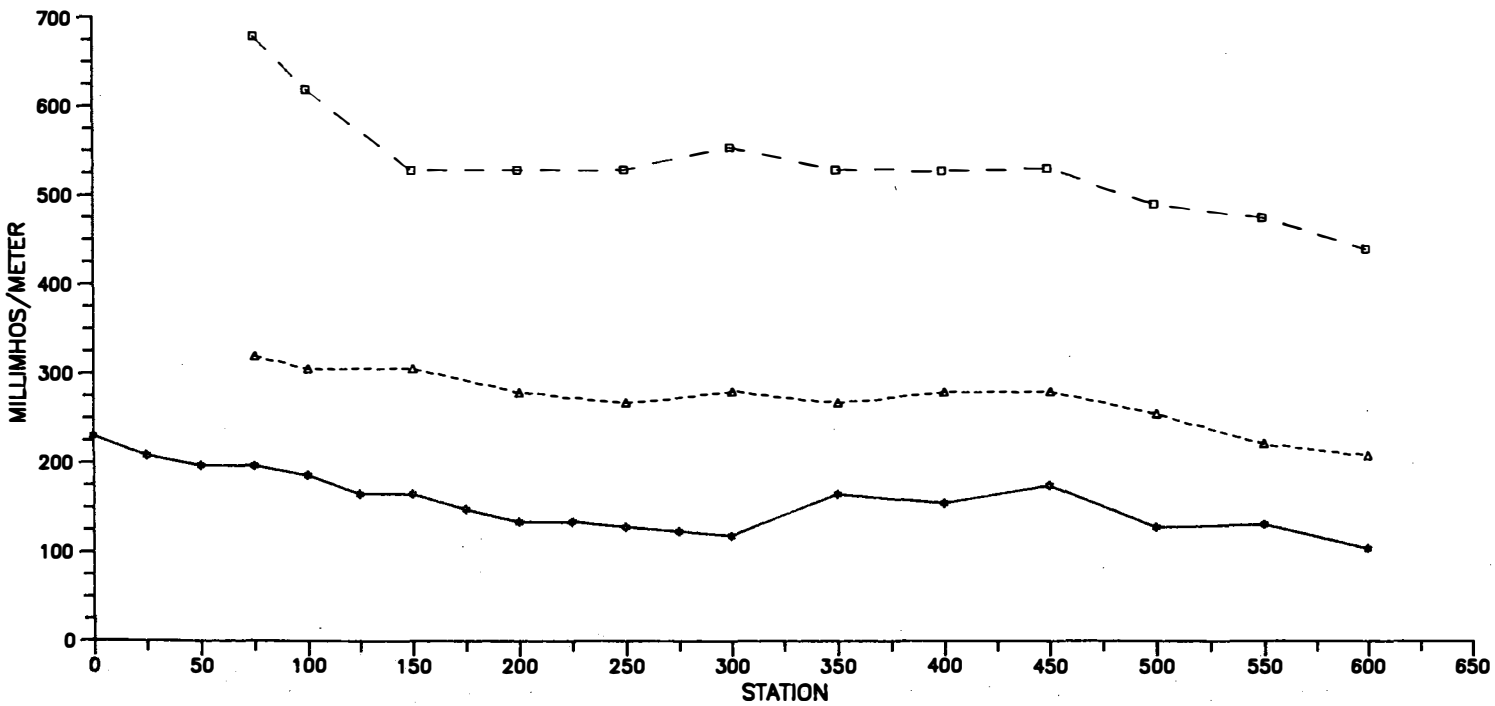
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE C3N
*HASEKO (HAWAII), INC.*
*CAMPBELL INDUSTRIAL PARK*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

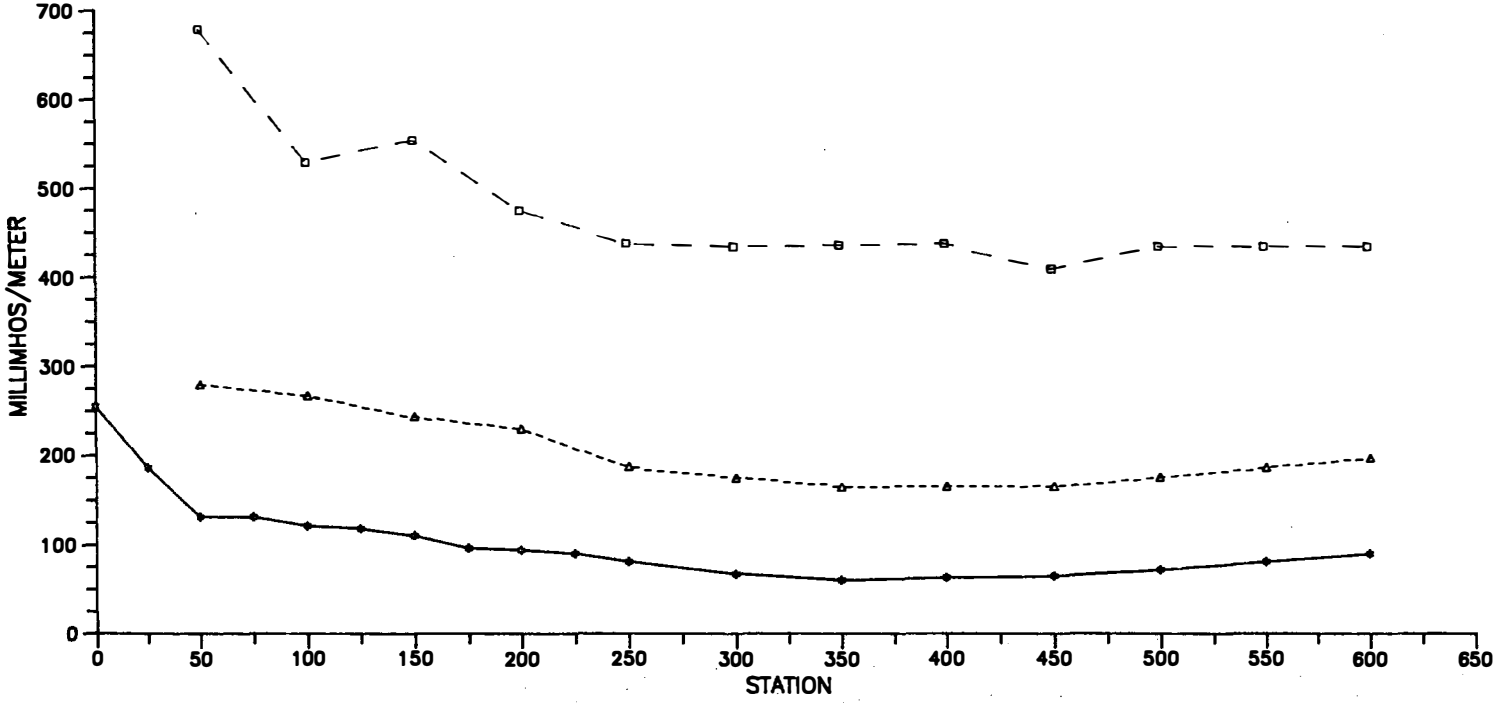
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE B1N
*HASEKO (HAWAII), INC.*
*BARBERS POINT HARBOR*

PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

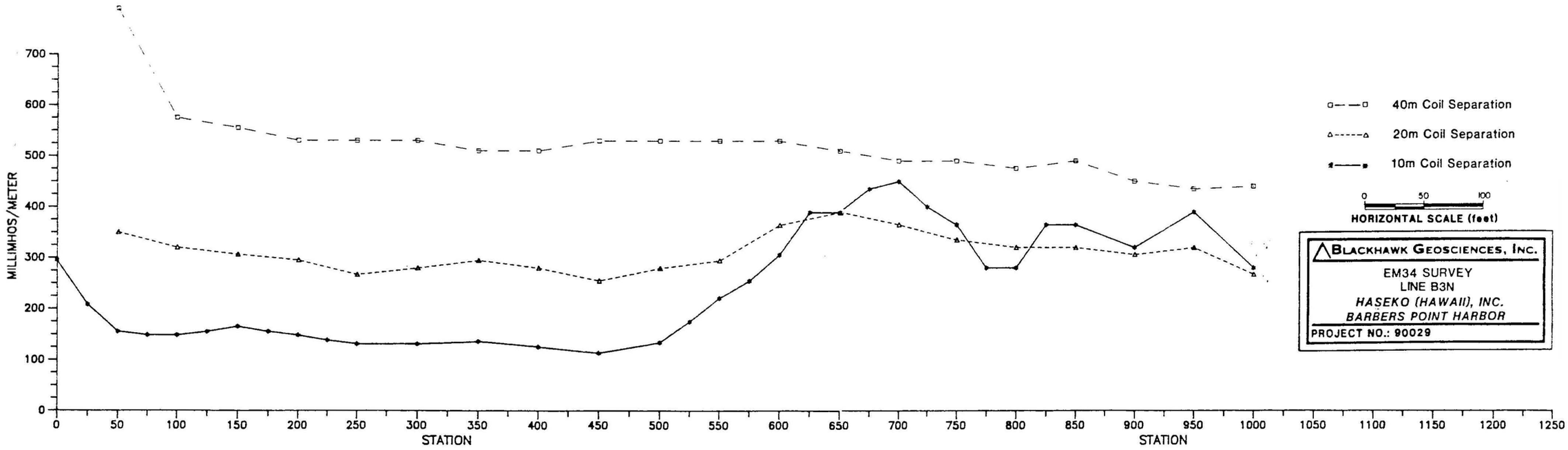
0 50 100

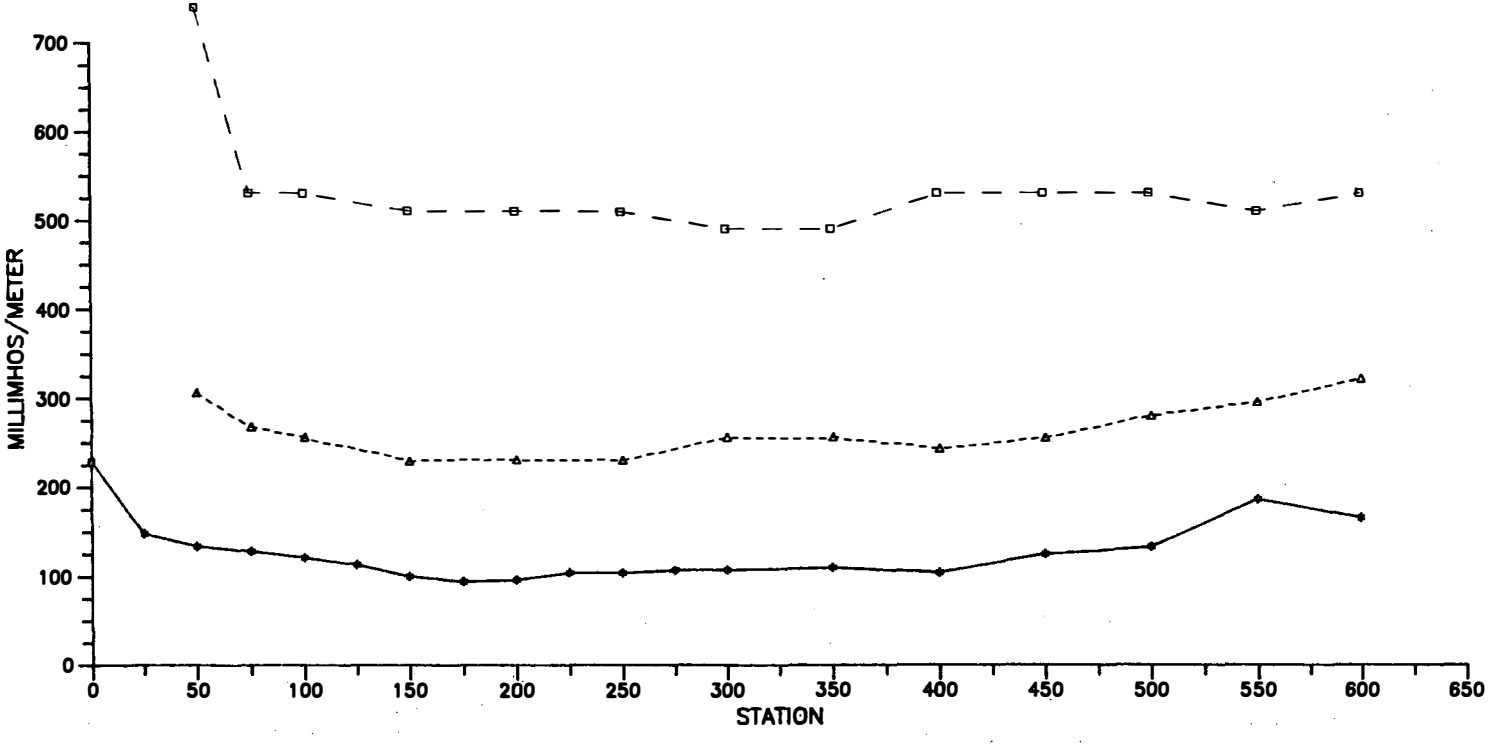
HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE B2N
*HASEKO (HAWAII), INC.*
*BARBERS POINT HARBOR*

PROJECT NO.: 90029


MILLIMHOS/METER
700
600
500
400
300
200
100
0
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250
STATION
STATION
40m Coil Separation
20m Coil Separation
10m Coil Separation
0 50 100
HORIZONTAL SCALE (feet)
BLACKHAWK GEOSCIENCES, INC.
EM34 SURVEY
LINE B3N
HASEKO (HAWAII), INC.
BARBERS POINT HARBOR
PROJECT NO.: 90029




40m Coil Separation

20m Coil Separation

10m Coil Separation

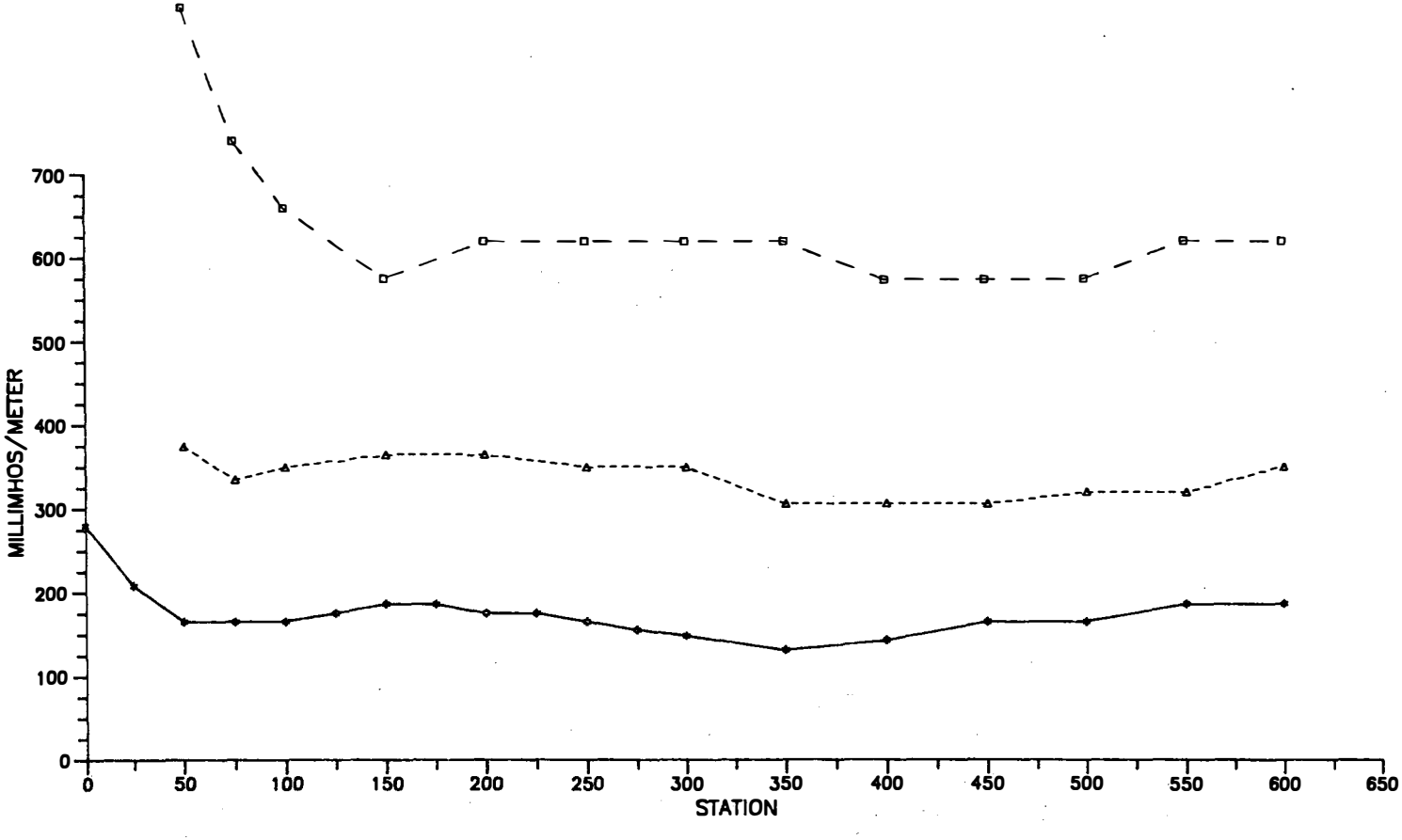
0 50 100

HORIZONTAL SCALE (feet)

BLACKHAWK GEOSCIENCES, INC.

EM34 SURVEY
LINE B4N
*HASEKO (HAWAII), INC.*
*BARBERS POINT HARBOR*

PROJECT NO.: 90029




□——□ 40m Coil Separation

△------△ 20m Coil Separation

*——* 10m Coil Separation

0 50 100

HORIZONTAL SCALE (feet)

**BLACKHAWK GEOSCIENCES, INC.**

EM34 SURVEY
LINE B5N
*HASEKO (HAWAII), INC.*
*BARBERS POINT HARBOR*

**PROJECT NO.: 90029**